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THE VALUE OF FIELD FORTIFICATIONS IN MODERN WARFARE

Volume I

Historical Evaluation and Research Organization (HERO)
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A qualitative and quantitative analysis of the functions, performance and effects of field fortifications was made in 14 combat operations in World War II and the October 1973 War and in four variants of one hypothetical combat example positing the defense of the US V Corps zone -- the Fulda Gap area of Western Germany -- in a surprise Warsaw Pact offensive against NATO forces, with and without the use of nuclear weapons. HERO's Quantified Judgment Method of Analysis of Historical Combat (QJMA), its computer-assisted

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20. ABSTRACT (Continued)
simulation of combat, the Quantified Judgment Model (QJM), and its Tactical Nuclear Sub-Model (TNSM) were used as analytic tools.

The analyses show quantitatively that, historically, field fortifications have invariably enhanced the combat capabilities of defenders in modern combat operations and substantially slowed the rates of advance of attackers. Similar results are derived for the hypothetical surprise attack in the US V Corps zone. Deterrence and operational implications for NATO are pointed out, and conclusions are drawn. These include quantitative conclusions based on the results of the QJM analyses.

EXECUTIVE SUMMARY

A qualitative and quantitative analysis of the functions, performance and effects of field fortifications was made in 14 combat operations in World War II and the October 1973 Middle East War and in four variants of one hypothetical combat example positing the defense of the US V Corps zone -- the Fulda Gap area of West Germany -- in a surprise Warsaw Pact offensive against NATO forces, with and without the use of nuclear weapons. HERO's Quantified Judgment Method of Analysis of Historical Combat (QJMA), its computer-assisted simulation of combat, the Quantified Judgment Model (QJM), and its Tactical Nuclear Sub-Model (TNSM) were used as analytic tools.

In eight of the historical combat examples, the defender made extensive use of field fortifications in a fortified-prepared defense. In six he did not (hasty-mobile defense). In each case three analyses were made: first, with the actual historical data; second, in a QJM replication of actual history (to validate QJM usage); and third, substituting factors to represent the opposite posture in the QJM.

The analyses show quantitatively that, historically, field fortifications have invariably enhanced the combat capabilities of defenders in modern combat operations and substantially slowed the rates of advance of attackers. Similar results are derived for the hypothetical surprise attack in the US V Corps zone. Deterrence and operational implications for NATO are pointed out, and conclusions are drawn. These include quantitative conclusions based on the results of the QJM analyses.

THE VALUE OF FIELD FORTIFICATIONS IN MODERN WARFARE

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CHAPTER I

INTRODUCTION

The objective of this project was to assess the effects of field fortifications in modern and future combat, particularly their potential value in defensive operations of NATO forces in Europe.

The general basis of the study is the qualitative and quantitative analysis of the functions, performance, and effects of field fortifications in fourteen combat operations in World War II and in the 1973 October War and in four variants of one hypothetical combat example positing the defense of the US V Corps Zone -- the Fulda Gap area of Western Germany -- in the event of a surprise Warsaw Pact offensive against NATO in the early 1980s. The quantitative analysis has made extensive use of HERO's Quantified Judgment Method of Analysis of Historical Combat (QJMA) and its computer-assisted simulation of combat, the Quantified Judgment Model (QJM), as analytic tools.

The historical combat examples, fourteen in all, were selected to include eight (Group A) in which the defender made extensive use of fortifications which apparently affected the outcome (fortified-prepared defense), and six (Group B) in which the defender had little or nothing in the way of prepared defensive positions (hasty-mobile or hasty-prepared defense). To test the extent to which the outcome was affected by the presence or absence of field fortifications*, each example was analyzed both as it was and as it might have been had it been in the other group. Using the QJM, three analyses were made of each example:

1. An analysis of the historical data.
2. A QJM replication of the combat example.
3. A QJM analysis in the alternate posture (hasty-mobile factors substituted for fortified defense factors, and vice versa).

A single example of hypothetical future combat in western Germany was analyzed in four variations:

1. A Warsaw Pact surprise conventional attack vs. a NATO hasty-mobile defense.
2. A Warsaw Pact surprise conventional attack vs. a NATO fortified-prepared defense.

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*See Appendix A for definitions of various postures used in this report.

3. A Warsaw Pact surprise tactical nuclear attack vs. a NATO hasty-mobile defense, with NATO responding in kind.

4. A Warsaw Pact surprise tactical nuclear attack vs. a NATO fortified-prepared defense, NATO again responding in kind.

As it did for the analyses of the historical combat examples, the QJM provided a structure and a conceptual basis for this analysis of hypothetical combat. For cases 3 and 4, in which a tactical nuclear exchange was posited, the QJM Tactical Nuclear Sub-Model (QJM-TNSM), the only known aggregated model of tactical nuclear combat, was utilized to complete the analysis. The sub-model is described in Appendix B.

Chapter II is a survey and qualitative examination of the role of field fortifications in modern combat, 1940-1973. While not exhaustive, it provides a context for, and a historical overview of, the important effects of fortifications analyzed in this report. The chapter shows that fortifications have been used in all important modern wars and that they have had a central and often a decisive role in determining their outcomes.

Chapter III contains brief narrative descriptions of the fourteen historical engagements that were selected for analysis. In their selection an effort was made to identify operations in a variety of geographical locations and with different types of fortifications. The absence of an operation involving one of the most famous of modern fortified systems, the Maginot Line, is regrettable but inevitable since in 1940 the German high command, recognizing that an attack on it would be foolhardy, bypassed it. The operation at Ahmadiyeh in the October 1973 War is included partly because the limited, but very effective, Israeli fortifications on the Golan Heights provide an example of the type of field fortifications that might be useful for NATO. It is instructive to see how the Syrians profited from the lesson at Ahmadiyeh in the belts of fortifications they have built around Damascus since 1973.

A. Examples of Fortified-Prepared Defenses

1. The attack of the German II SS Panzer Corps against the Soviet XXIII Guards Rifle Corps at Kursk-Prokhorovka, 4-8 July 1943;

2. The attack of the German XLVIII Panzer Corps against the Soviet Sixth Guards and First Tank Armies at Kursk-Oboyan, 5-13 July 1943;

3. The defense of the Nikopol bridgehead by the German 35th Infantry Division against the attack of the Soviet 109th Rifle Division, 31 January-5 February 1944;

4. The German Fourteenth Army offensive against the US 45th Infantry Division in the "Bowling Alley" sector of the Anzio beachhead, 16-19 February 1944;

5. The US XIX Corps penetration of the West Wall near Aachen, 2-7 October 1944;

6. The attack of the Soviet 57th Guards Rifle Division against the German 303d Infantry Regiment at Seelow Heights, west of Berlin, 16-17 April 1945;

7. The attack by the Egyptian Second Army against the Israeli Bar Lev Line, 6 October 1973;

8. The Syrian attack against the Israeli fortifications in the Ahmadiyeh sector of the Golan Heights, 6-7 October 1973.

B. Examples of Hasty-Prepared Defenses

1. The attack by the British 1st Infantry Division against the German 3d Panzer Grenadier Division in the Aprilia sector of the Anzio beachhead, 25-26 January 1944;

2. The defense of Terracina by the German 94th Infantry Division against the US 85th Infantry Division, 22-23 May 1944;

3. The attack of the US 3d Infantry Division against the German Hermann Goering Panzer Parachute Division at Valmontone, 1-2 June 1944;

4. The defense of the Sauer River line during the battle of the Bulge by the US 4th Infantry Division, 16-17 December 1944;

5. The attack of the Israeli Adan Division at Jebel Geneifa, Egypt, 19-22 October 1973;

6. The combat between the Israeli Peled Division and the Syrian 5th Infantry Division at Tel Fars, 8-10 October 1973.

Each of the fourteen historical operations is examined in the three variations described earlier in this section, and the combat outcome in each is described and analyzed individually and comparatively in five categories: daily percent personnel casualties, daily percent tank losses, distance advanced per day (in kilometers), percent personnel casualties

per kilometer, and percent tank losses per kilometer. From the results of this analysis it is possible to determine the real effects of fortifications on historical combat outcomes.

Chapter IV presents a narrative base and qualitative and quantitative analyses of the role of fortifications in the hypothetical engagement in the Fulda Gap area of Western Germany in the 1980s. The hypothetical future combat is examined in the four variations described above, and the combat outcome in each scenario is described and analyzed individually and comparatively in the five categories. The chapter provides, through an extrapolation from modern historical experience, simulations of the effects fortifications would be likely to have in conventional or tactical nuclear warfare "worst case" combat events in Europe in the future.

Chapter V provides a comprehensive quantitative analysis of the historical and hypothetical engagements. The resulting statistical comparisons of the effects of posture on engagement outcomes provide reliable and accurate measures of the effects of field fortifications in historical and future combat.

Chapter VI summarizes the findings of the study and presents the conclusions that flow from the analyses. The chapter emphasizes particularly the likely effects the construction of a fortified barrier for NATO would have on future combat in Europe and recommends prompt construction of such a barrier.

Appendix A includes a list of Posture Definitions as used in the text. Appendix B briefly describes HERO's Tactical Nuclear Sub-Model (TNSM). This is an extract from report DNA 5054-2, a classified discussion of HERO's Tactical Nuclear Sub-Model.

The principal participants in this project were Trevor N. Dupuy, C. Curtiss Johnson, Paul Martell, Grace P. Hayes, and Thomas Betsock.

CHAPTER II

QUALITATIVE SURVEY OF THE ROLE OF FIELD FORTIFICATIONS IN MODERN WAR

History relates, and archaeological evidence confirms, that, throughout the ages, fortifications have been an important and frequently-employed asset in warfare. In modern warfare, especially since the industrial revolution of the 18th and 19th centuries, and the beginnings of the ongoing technological revolution, radically changed the conduct of warfare by making possible the development and widespread use of weapons of increased complexity and much increased theoretical lethality, men and armies have had to resort more frequently than ever before to the armor of fortifications.

In World War I machine guns, modern shrapnel, and high explosive shells drove opposing armies into extensive trench systems on the Western Front, in the East, and in northern Italy and the Balkans. For the first time in history* armies fought a war in which there were no flanks; victory could be gained only by costly frontal attacks or by exhausting the enemy's ability or will to make war. The appearance of the first tanks in 1916, and, still later, the introduction of "Hutier" tactics by the Germans, restored a measure of mobility to the battlefield, but combat in the Great War was characteristically a combat of trenches and artillery.

During the interwar years, many European nations, having analyzed the military experience of World War I, erected permanent fortifications along their frontiers, primarily for strategic purposes. The best remembered of these works are the French Maginot Line and the German West Wall.

Both permanent and field fortifications were important factors in all World War II land campaigns. Among the many examples that might be cited, the following brief descriptions will illustrate the effects of fortification systems in the war.

The Mannerheim Line was a Finnish defense line extending across the Karelian Isthmus north of Leningrad. It was a very important position because it convered the only area of the Russo-Finnish frontier in which

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*Although presaged to some extent in the American Civil War.

the Russians could concentrate large numbers of troops for offensive operations against Finland. The fortifications -- mostly pillboxes -- were well integrated with the rugged, wooded terrain of the area and were supplemented by wire, mine, and water obstacles.

The line was attacked twice by the Soviets. The first attack, in December 1939, was easily repulsed; the second attack, during 11-21 February 1940, led to a breakthrough, but only after the Soviets had suffered tremendous casualties. In fact, Soviet losses were so heavy that their assault forces had to be regrouped and heavily reinforced before the offensive could be resumed.

The fall of the line led to the defeat of Finland, and a Soviet-Finnish peace treaty was signed on 12 March. There is no doubt, however, that, had the line not existed, the Soviets would have defeated Finland in December 1939. In this context, the line well fulfilled its role of protecting the most vulnerable approaches to the Finnish heartland.

The Maginot Line was a very powerful continuous defensive system designed to protect the eastern frontier of France from invasion. In its strongest sectors it consisted of concrete and steel forts, casemated and turreted, covered by antitank obstacles, mines, wire, advanced works, fortified houses, and in some instances, by lighter field fortifications. Two sectors of the line were more heavily fortified than others: the Region de la Lauter and the Region de Metz. Significantly, the flanking sectors and the sector in between these two regions were relatively weakly fortified.

The "failure" of the Maginot Line to protect France from the German invasion in 1940 is often cited as an example of the "futility" of fortification systems. But an examination of the historical record reveals that this was not the case. The line itself was never seriously tested. There were no significant fortifications along the Franco-Belgian frontier. The German attack enveloped the line through the weak blocking sector of the Ardennes -- a sector the French General Staff considered "impenetrable," and which, at General Petain's urging, they had refused to fortify.

North Africa. The campaigns in North Africa are commonly regarded as epitomizing unfettered, free-wheeling mobile warfare in World War II, but, in fact, fortifications shaped the war in this theater. (One need

only mention Tobruk, Bir Hacheim, El Alamein, and Mareth to be reminded of this.) Both Rommel and Montgomery made extensive use of field fortifications, and Rommel, at El Alamein (in the Battle of Alam Halfa), was denied the quick win he needed and ultimately was defeated because of Montgomery's clever use of field fortifications integrated with extensive minefields.

Italy. The war in Italy was essentially a war of fortifications, mostly German -- except at Anzio, where both sides fortified extensively. This circumstance resulted from German Field Marshal Kesselring's decision to defend the Italian peninsula from successive, powerful fortified lines constructed roughly east-west across the peninsula. The grinding, costly, and relentless campaigns to breach and reduce these lines, one after the other, delayed Allied victory in Italy until 2 May 1945.

The West Wall (called the Siegfried Line by the Allies) was a near-continuous barrier system built by Germany along its western frontier in the late 1930's. The defenses consisted mainly of concrete and steel pillboxes, individual and in clusters, capable of mounting machine guns and light antitank guns. The pillboxes were mutually supporting. There were also concrete and steel observation posts and a few emplacements for artillery weapons. Protecting the approaches to the pillboxes were dragons' teeth antitank obstacles, wire, and mines. In addition, the line was closely integrated with terrain features in all areas.

The West Wall was considered obsolete in 1944, and nearly all of its supporting equipment had been dismantled and shipped to the Atlantic Wall system facing the English Channel. Nonetheless, it still presented a formidable obstacle to advancing Allied armies. German community digging and field fortifications improved the defenses in certain sectors but not to the extent desirable, because the collapse of German forces in France occurred with such rapidity after the Normandy breakout battles, and the Germans had only a month to prepare the neglected fortified line for combat.

The protection afforded by the West Wall, however, did allow the Germans to reorganize and present a front short of the Rhine, following their withdrawal across northeastern France and Belgium. Had the West Wall not existed, World War II in the west would almost certainly have ended in the autumn of 1944.

The Stalin Line and "Barbarossa." The Soviets consider the unreadiness of their fortifications at their western frontier in 1941 to have been an important contributing factor in their initial defeat and the rapid penetration of European Russia by the German armies in Operation "Barbarossa." Many of the fortified areas built along the "old" frontier (the Stalin Line) were not functional in 1941. Their garrisons, armament, and equipment had been removed. A new line, located some 100 kilometers west of the Stalin Line, had been only partially completed, and the fortifications, in most cases, had not been occupied. In areas where the fortifications were complete and were garrisoned, the Germans met with stiff resistance which considerably delayed their advance.

Moscow. As German Army Group Center moved eastward, the Soviets, as early as August 1941, began constructing field fortifications around Moscow. Soviet military analysts point out that if it had not been for the thousands of kilometers of trenches, the antitank ditches, and the minefields of the Moscow defenses, the Germans might have taken the city. This would have had catastrophic consequences for the Soviet state.

Kursk. When the Germans launched their offensive toward Kursk in July 1943, they attacked what was perhaps the most elaborate system of field fortifications ever constructed. The basis of the work was an extensive system of trenches totalling nearly 6,000 kilometers in aggregate length, plus strongpoints, 1,000,000 mines, antitank ditches, and wire and other obstacles. This system determined the outcome of the battle. Despite their superiority along the axes of main effort, the Germans could not break through these powerful and deeply echeloned Soviet defenses. Counterattacked by strong Soviet reserves in the depth of the fortified area, the Germans were forced to withdraw. Had it not been for the foresight of the Soviet High Command in basing the defense of the salient on an elaborate fortified system, the Germans most probably would have broken through and encircled and destroyed nearly one million Soviet troops.

Soviet Offensives, 1943-1944. The Soviets launched a general offensive after the Kursk battle which lasted two years and brought them to the gates of Berlin. To combat the Soviet offensives, the Germans employed field fortifications extensively, not only to protect their

troops and weapons but also to protect the assembly areas of mobile reserves, which were then employed in counterattacks and counteroffensives.

East Prussia and Berlin. In the winter of 1945, when Marshal Zhukov's 1st Byelorussian Army Group was pushing directly toward Berlin on the Warsaw-Berlin axis, it was forced to abandon its primary objective (Berlin) and turn to the northwest to assist in the reduction of the German fortifications in Pomerania. This change in the axis of advance of Zhukov's army group gained the Germans almost a month in which to improve the fortifications along the Oder River on the approaches to Berlin. When Zhukov's troops resumed the attack against Berlin, the German fortifications protecting the city had been improved to the extent that the Soviets were seriously delayed and suffered many more casualties than they might have against a hasty-mobile or a prepared defense.

In the years since World War II, field fortifications have played important roles in three major conflicts: the Korean War, the Indochina-Vietnam wars, and the 1973 Arab-Israeli War. A resume of the effects of field fortifications in these wars follows:

Korea. At the outbreak of the Korean War, the South Korean forces, although surprised and considerably disrupted by the North Korean invasion, used hasty field fortifications and obstacles to great effect in slowing the advance of the invader. In 1951, as soon as the front stabilized approximately along the 38th Parallel, both sides extensively fortified their positions. These fortifications were instrumental in checking major offensive operations and led to the protracted stalemate that characterized the last phase of the war.

Vietnam. The prevalence and importance of field fortifications in the conflicts fought in Southeast Asia cannot be overstated. The French, in the Indochina War (1945-1954), constructed two extensive linear fortified positions in an attempt to check the Viet Minh. One position was along the Chinese border, in the region Lang Son-Cao-Bang. The trace of this line, which was probably begun in the 19th Century and has been improved continually since, was that which confronted the Chinese during their 1979 offensive actions against North Vietnamese. The second line, called the "De Lattre Line," enclosed the Hanoi-Red River delta area. The effects of these fortifications were vitiated because the Viet Minh infiltrated the areas they covered. The line along the

Chinese border fell very quickly to Viet Minh forces when attacked from front and rear in October 1950; the French, in this debacle, lost 6,000 men, 13 guns, and enough materiel to equip a division. The De Lattre Line, on the other hand, was rarely attacked directly.

The fortress at Dienbienphu was constructed by the French near the Laotian border as part of an elaborate plan to decoy Viet Minh forces into a set-piece battle in which they could be destroyed by artillery and airpower. In the event, the French miscalculated and were themselves "pocketed." After one of history's most famous sieges (20 November 1953-7 May 1954), the French forces at Dienbienphu capitulated, and French control over Indochina was virtually ended.

Under the Americans, fortifications were important elements in local defense. Fortified hamlets were centers of resistance and refuge in the countryside. In an adaptation of an idea that dates back to the Boer War and the Spanish reconcentrado system in Cuba, US forces used fortified hamlets as a method of protecting civilians and ensuring their loyalty; the system also helped to segregate the guerrilla from the loyal or neutral sectors of the population.

Certain strategically important areas were subject to extensive fortification on the strongpoint principle. Khesanh, for example, was a fortress constructed to command a major North Vietnamese supply route. It was besieged by NVA troops during 21 January-8 April 1968, but US forces, despite having to be supplied by air during part of the siege, successfully repelled every NVA attempt to take the fortress.

The fortifications constructed in Vietnam were mostly strongpoints. Extensive use of locally available materials characterized their construction. Typically, they were built of earth and sandbags, with overhead cover and well-protected firing positions. Wire, mines, booby traps, ditches, and bamboo abatis were used extensively to protect the combat positions.

The October 1973 War. The fortifications of the Bar Lev Line, sparse and lacking in depth as they were, served the purposes for which they were designed, namely, to delay and impede the attacker and to provide time to enable the defender to mount a counterattack with mobile reserves. There is no doubt that the Bar Lev Line contributed significantly to the ultimate success of the Israelis on the Sinai front.

On the Golan front, too, fortifications were a significant factor in the Israeli victory. The fortifications and obstacles on the Golan Heights helped to dilute the effects of the Syrian surprise attack and were the principal reason the Syrians were unable to penetrate into Galilee.

CHAPTER III

THE CASE STUDIES

EXAMPLES OF FORTIFIED-PREPARED DEFENSES

Kursk-Prokhorovka, 4-8 July 1943

In July 1943 the Soviet XXIII Guards Rifle Corps held a 31-kilometer wide sector stretching from Dragunskoye to Chernaya Polyana on the southern flank of the massive, heavily fortified Kursk bulge, which was located in the central region of the Eastern Front. In the weeks preceding the German attack on the salient, the Soviet corps laid some 37,000 antitank mines and 27,700 anti-personnel mines, strung 90.7 kilometers of barbed wire obstacles, dug 200 kilometers of trenches and 38 kilometers of antitank ditches, and built numerous dugouts, shelters, and other fortifications. The main defensive area was 20 kilometers deep, with fortified strongpoints distributed in its front and rear. The area consisted of two defensive zones, each five to seven kilometers deep and composed of two or three defensive positions. Each defensive position had two or three lines of trenches.

Facing the Soviet XXIII Guards Rifle Corps was the German II SS Panzer Corps of the Fourth Panzer Army. The German corps was composed of three panzer divisions: SS Das Reich, SS Liebstandarte Adolf Hilter, and SS Totenkopf. Its mission was to break through the Soviet defenses on a narrow, ten-kilometer front with two divisions -- Das Reich, and Liebstandarte (some 43,000 men and 301 tanks) -- and advance north toward Prokhorovka. Only about one-third of the Soviet XXIII Guards Rifle Corps defended the immediate assault sector. The Totenkopf Division had the mission of securing the right flank of the planned penetration, while units of the adjacent XLVIII Panzer Corps would secure the left flank.

The terrain on the attack front consisted of low hills, small streams, and scattered towns, woods, and ravines. The ground rose generally to the north, favoring the defender. At the start of the attack the ground was muddy, but the weather was good. The German axis of advance followed the main Belgorod-Kursk highway. The Germans had an initial advantage in troops and tanks, but neither side had established air superiority.

On 4 July the Germans made preparatory attacks on Soviet outposts located from two to three kilometers in front of the main defensive area. After fierce fighting, the Soviet defenders of these outposts withdrew in the morning of 5 July.

The Germans launched their main attack on the morning of 5 July with the Liebstandarte Division on the left and the Das Reich Division on the right. Despite staunch resistance from entrenched Soviet troops, forward elements of the Panzer Corps advanced ten kilometers and reached Bykovka by nightfall. However, the main assault group advanced only about four kilometers.

On 6 July the Germans continued to advance, but largely in a narrow, two-kilometer wide corridor. A German reconnaissance battalion took Luchki, ten kilometers northeast of Bykovka, in the evening, while other reconnaissance units reached the edge of Kalinin, two kilometers northeast. However, the heavily fortified Yakovlevo area to the left and rear of the advancing German forces resisted all attacks, and the main assault elements advanced only five or six kilometers.

Large Soviet reinforcements, including the V Tank Corps and about half of the III Mechanized Corps, arrived on 7 July and were immediately committed to combat. The Germans were still superior to the Soviets in personnel strength, but the Soviets now had more tanks, and the Panzer Corps attack began to slow. On 12 July Soviet counterattacks forced the Germans to assume the defensive.

Table 3-1(A) shows the outcomes for the historical engagement at Kursk-Prokhorovka. The attacker's average daily advance along the main axis was 3.74 kilometers. German plans called for a breakthrough of Soviet defenses in the Prokhorovka area in the first 24 hours of the offensive and anticipated that the assault elements would reach Prokhorovka itself, some 35 kilometers from the front line, after 36 hours. In fact, as the table shows, the historical rates of advance were much lower than these extremely optimistic planned rates.

During the first two days of the operation, the Germans advanced only about nine kilometers, ending the second day still about 25 kilometers short of their goal. The cumulative advance, through 8 July, was 14.95 kilometers. However, it should be noted that even this advance was on a narrow, restricted front. The reconnaissance and light mobile elements of the attack group advanced farther by bypassing Soviet strongpoints, but,

TABLE 3-1. THE EFFECTS OF FORTIFICATIONS: KURSK-PROKHOROVKA, 4-8 JULY 1943

A. HISTORICAL WITH FORTIFICATIONS

Dates		Days	Personnel Strength	Cas	%/Day	Tanks Strength	Losses	%/Day	Distance Km	/Day	% Cas /Km	% Tanks /Km
4-8 Jul	A	4.0	43,000	1,692	0.98	301	95	7.89	14.95	3.74	0.26	2.11
	D		30,300	3,800	3.14	111	49	11.04			0.84	2.95

B. QJM REPLICATION WITH FORTIFIED DEFENSE

4-8 Jul	A	4.0	43,000	2,420	1.41	301	137	11.38	6.76	1.69	0.83	6.73
	D		30,300	3,300	2.72	111	43	9.68			1.61	5.73

C. HYPOTHETICAL HASTY DEFENSE

4-6 Jul	A	1.5	43,000	595	0.92	301	40	8.86	33.00	22.00	0.04	0.40
	D		30,300	1,770	3.89	1	1	100.00			0.18	--

in doing so, created dangerous gaps between themselves and the main assault group. The Soviets skillfully exploited these gaps by attacking German formations on open flanks and on the rear.

Personnel casualties and tank losses at Kursk-Prokhorovka were heavy for both sides. The Soviets were determined to prevent a breakthrough at any cost and, because of their fortified posture, were able to inflict heavy casualties on the Germans.

The attacker's average daily personnel casualties were 423 men or 0.98%; those of the defender were 950 men or 3.14%. The average daily tank losses of the attacker were 23.75 tanks or 7.89%; those of the defender were 12.25 tanks or 11.04%. The average percent casualties per kilometer advanced or retreated was 0.26% for the attacker and 0.84% for the defender. The average percent tank losses per kilometer was 2.11% for the attacker and 2.95% for the defender.

Table 3-1(B) shows the computer-generated outcomes of the QJM replication of the battle of Kursk-Prokhorovka. The attacker's average daily advance rate is 1.69 kilometers, smaller than the historical advance rate by a factor of 0.45. The average daily personnel casualties of the attacker are 605 men or 1.41%; those of the defender are 825 men or 2.72%. These figures differ from the same historical figures by factors of 1.44 and 0.87 respectively. The attacker's average daily tank losses are 34.25 tanks or 11.38%; those of the defender are 10.75 tanks or 9.68%. These figures correspond to the same historical figures by factors of 1.44 and 0.88 respectively. The average percent casualties per kilometer is 0.83% and 1.61%. These figures compare to the same historical figures by factors of 3.19 and 1.92, respectively. The average percent tank losses per kilometer is 6.73% for the attacker and 5.73% for the defender. These figures compare to the same historical figures by factors of 3.19 and 1.94 respectively. The outcome data for the QJM replication shows that the computer has quite adequately replicated the personnel casualties and tank losses of the combatants in this famous struggle but has somewhat underestimated the attacker's average advance rate. The indication is that the Germans did appreciably better against the massive and complex Soviet fortification system than they had any right to expect, but it should be noted that even in advancing at the historically higher than average rate, the Germans were more often than not bypassing defensive complexes and masses of troops and materiel which then created problems for the continued offensive thrust of the operational mass.

Table 3-1(C) shows the QJM-generated outcomes of a hypothetical engagement at Kursk-Prokhorovka, assuming that the Soviets had adopted a hasty-mobile defensive posture. The attacker's average daily rate of advance is 22.00 kilometers, which shows that, against the hasty defense, the Germans would have reached Prokhorovka in 36 hours, thus attaining their historical goal. Such a rapid advance would have denied the Soviet reserves the time needed to organize an effective defense or a counterattack. The Soviet reserves would have been committed piecemeal and would not have benefitted from previously prepared defensive positions. Thus, they would have been easier to defeat.

The attacker's average daily casualties were 397 men or 0.92%; those of the defender are 1,180 men or 3.89%. Compared to the same figures for the historical fortified defense, the attacker's average daily personnel casualties have declined by a factor of 0.94, while those of the defender have increased by a factor of 1.24. The attacker's average daily tank losses are 26.67 tanks or 8.86%, an increase over the same figure for the historical battle by a factor of 1.12. The defender, in the hasty defense, had only one armored fighting vehicle. The attacker reached his operational objective on 6 July; so the defender could not be reinforced with armor as he was in the historical battle. Thus the delay imposed upon the attacker by the fortifications was the major element in the ultimate historical Soviet success.

The percent casualties per kilometer in the hasty defense are 0.04% for the attacker and 0.18% for the defender. These figures are lower than the same figures for the historical fortified defense by factors of 0.15 and 0.21 respectively. The attacker's percent tank losses per kilometer is 0.40%. This figure is lower than the same historical figure by a factor of 0.19.

Kursk-Oboyan, 5-15 July 1943

The Soviet winter offensive of 1942-1943 led to the formation of a massive salient west of Kursk, between Orel and Belgorod in the central region of the Eastern Front. In Operation "Citadel," begun on 4 July 1943, German forces north and south of the bulge launched converging attacks, hoping to cut off the salient near its base.

The Soviets, anticipating the German offensive, had heavily fortified the bulge, and assigned two Soviet army groups to defend it. The Central Army Group occupied the northern and northwestern sectors, and the Voronezh Army Group was responsible for the southern and southwestern sectors.

The main defensive area, about 20 kilometers deep, was arranged in two fortified zones, each five to seven kilometers deep, the two zones separated by about five kilometers. Each fortified zone contained three successive defensive positions. Each of these positions had two or three lines of trenches, as well as minefields, antitank ditches, pillboxes, bunkers, and barbed wire obstacles. The first position of the first zone probably constituted the strongest part of the main defensive area. Behind the main defensive area, for a depth of about 15 kilometers, obstacle centers were built. Covering from two to five kilometers each, these were placed in areas most vulnerable to potential German penetrations. The Soviet hope was that the defense of the fortifications would slow, and eventually halt, the German attack and cause heavy casualties. After the German force was weakened, the Soviet command planned to commit its reserves and counterattack.

This case study deals with the operations of the XLVIII Panzer Corps of the German Fourth Panzer Army, which attacked the southern sector of the bulge. The corps assault group consisted of three divisions: the 3d Panzer Division, the Gross Deutschland Panzer Grenadier Division, and the 11th Panzer Division. The corps's two remaining (infantry) divisions protected the flanks of the assault group.

Following a preparatory assault on Soviet outposts in the afternoon of 4 July, the corps launched its main attack north toward Oboyan on the morning of 5 July. The attacking force, which had 58,556 men and 426 tanks, advanced to attack in a ten-kilometer wide sector between Korovino and Tomarovka. The defending Soviet force in this sector (elements of the Sixth Guards Army) had, initially, 7,500 men and 37 tanks. However, as soon as the Soviets recognized that this was a German main attack sector, reinforcements were committed.

The weather was generally good for the first four days of the German offensive, although rain on 4/5 July resulted in some muddy ground. The terrain contained numerous ravines, woods, low hills, and streams, making it moderately difficult to cross. Neither side had established air superiority. The Germans had an advantage in combat power for the first four days of the attack.

During the first phase of the battle (5-7 July), the Germans broke through the first defense zone, overcoming numerous antitank ditches, water-filled ravines, muddy roads, minefields, and fierce Soviet resistance.

In the second phase (7-9 July), the Germans entered the less fortified second zone but encountered massive Soviet reinforcements. The Soviet First Tank Army had begun arriving on the evening of 6 July, and elements of the Thirty-Eighth and Fortieth Armies, which had been deployed on the right of the Sixth Guards Army, transferred to that army on 7 July. Also, some elements of the Soviet General Headquarters Reserve arrived on that day.

It was during this second phase that German attempts to cross the Pena River and advance directly north failed. After this, the attack axis was shifted to the northeast, away from the river and toward the towns of Lukhanino and Syrtsevo. The Soviet defenders of the heavily-fortified towns resisted attacks until the evening of 9 July.

In the third phase of the battle (9-15 July) the German offensive slowed considerably. On 9 July the Soviets started withdrawing from positions on the northern bank of the Pena River; the next day the Germans again shifted their axis of advance (this time to the northwest and west) in an attempt to cut off these withdrawing troops. The 3d Panzer Division moved west, taking Berezovka on the morning of 11 July. Elements of the Gross Deutschland Division moved northwest, taking part of Kalinovka on 10 July. The 11th Panzer Division continued to advance due north, taking Pokrovskiy, Krasnaya Polyana, and Berezoviy on 10 July. All of these movements were resisted by entrenched Soviet troops and by local counter-attacks.

Heavy rain during the night of 10-11 July further slowed the German advance. The 11th Panzer Division gained no ground in its attempt to continue its attack northward on 11 July, and the other two German divisions spent the day mopping up Soviet troops in fortified positions in the Berezovka area.

On 12 July the Soviets launched a major counterattack, thwarting all further German offensive operations in the Oboyan sector. By 15 July the XLVIII Panzer Corps had taken up defensive positions, its attempt to break through having failed.

Table 3-2(A) shows the engagement outcomes of the historical battle in the Oboyan sector of the Kursk bulge. Note first that the attacker's average daily advance rate is 3.00 kilometers. At the start of the battle the German command expected to break through the Soviet main defensive area during the first 24 hours of the offensive -- a planned advance of from 20 to 25 kilometers. The historical daily average advance rate shows just how unrealistic German estimates of their capabilities were. During the first two days of the attack the XLVIII Panzer Corps advanced on average only 5.5 kilometers a day. Yet even this advance rate is somewhat deceiving, because it reflects primarily the advance rate of the leading elements on a very narrow, restricted front and disregards heavy fighting in the rear of the leading attack elements. The slowness of the German advance permitted the Soviets to bring in reinforcements and commit them in defensive positions inside the main defensive area. This further slowed the German advance. During 7-9 July, attacking the newly-arrived troops, which were deployed in well-prepared defensive positions, the German rate of advance decreased to 2.8 kilometers per day. During 9-15 July, the Germans advanced on average just 2.1 kilometers per day. For the 11-day period the average advance rate was 3.0 kilometers per day.

The average daily personnel losses of the attacker were 626 men or 1.07%; those of the defender were 2,762 men or 3.09%. The average daily tank losses of the attacker were 31.91 tanks or 6.70%; those of the defender were 69.18 tanks or 18.75%.

The average percent personnel casualties per kilometer advanced or retreated was 0.36% for the attacker and 1.03% for the defender. The average percent tank losses per kilometer was 2.23% for the attacker and 6.25% for the defender.

Table 3-2(B) shows the outcomes of the QJM replication of the battle of Kursk-Oboyan. The attacker's average daily advance rate is 2.99 kilometers, approximately the historical rate. The average personnel daily casualties of the attacker are 674 men or 1.15%, 107% of the attacker's historical average daily casualties. The average daily personnel casualties of the defender are 2,549 men or 2.85%, 92% of the historical figure. The

TABLE 3-2. THE EFFECTS OF FORTIFICATIONS: KURSK-OBOYAN, 5-15 JULY 1943

A. HISTORICAL WITH FORTIFICATIONS

Dates		Days	Personnel Strength	Personnel Cas	Personnel %/Day	Tanks Strength	Tanks Losses	Tanks %/Day	Distance Km	Distance /Day	% Cas /Km	% Tanks /Km
5-15 Jul	A	11	58,556	6,888	1.07	476	351	6.70	33.00	3.00	0.36	2.23
	D		89,443	30,382	3.09	369	761	18.75			1.03	6.25

B. QJM REPLICATION WITH FORTIFIED DEFENSE

5-15 Jul	A	11	58,556	7,418	1.15	476	321	6.13	32.90	2.99	0.39	2.05
	D		89,443	28,035	2.85	369	819	20.18			0.95	6.75

C. HYPOTHETICAL HASTY DEFENSE

4-5 Jul	A	2	61,455	430	0.35	522	26	2.49	60.06	30.03	0.01	0.08
	D		42,728	2,367	2.77	55	55	50.00			0.09	1.67

average daily tank loss for the attacker is 29.18 tanks or 5.13%, 91% of the historical figure; that of the defender is 74.45 tanks or 20.18%, 108% of the historical figure. The average percent personnel casualties per kilometer is 0.39% for the attacker and 0.95% for the defender. The average percent tank losses per kilometer is 2.05% for the attacker and 6.75% for the defender. The figures provide good approximations of the historical figures.

Table 3-2(C) shows the QJM-generated outcomes of a hypothetical engagement at Kursk-Oboyan, assuming that the Soviets had not fortified their defensive lines. The attacker's average daily advance rate was 30.03 kilometers, which indicates that the XLVIII Panzer Corps would have broken through the main defensive area and defeated the Soviet Sixth Guards Army. Such an advance rate would have prevented the Soviet command from deploying its reserves in a timely and organized fashion, as was done historically. The First Tank Army, the backbone of the operational reserve of the Voronezh Army Group, could not have been committed as planned but would probably have entered the battle piecemeal, its effectiveness much decreased. Under these circumstances, the XLVIII Panzer Corps would probably have reached the city of Oboyan, its immediate objective, on 6 July.

The average daily casualties of the attacker are 215 men or 0.35%; those of the defender are 2,367 men or 2.77%. The average daily tank losses of the attacker are 13 tanks or 2.49%; those of the defender are 55 tanks or 50.00% per day.

Since the hypothetical engagement covers only two days, it is difficult to make comparisons of its outcomes with those of the historical engagement. However, the projected losses in personnel and materiel for the hypothetical engagement are much lower than those of the historical battle and its QJM replication. A comparison of percent personnel casualties per kilometer for both engagements shows that the attacker's casualties would have declined by a factor of 0.03 against the hasty defense, while those of the defender would have declined by a factor of 0.09. A similar comparison for tank losses reveals that against the hasty defense the attacker's tank losses would have decreased by a factor of 0.04; those of the defender by a factor of 0.27.

This hypothetical case shows the value of the Kursk fortifications. Defenders need time to bring reserves up to the sector being attacked. Fortifications slow the attacker and grant the defender that time. At Kursk-Oboyan the Soviet First Tank Army and other units had time to reinforce the Sixth Guards Army effectively because of the fortifications system.

A secondary but not negligible matter of importance is the value of fortifications in wearing away the attacker's strength. At the time the Soviets launched their counterattack on 12 July, the Germans had lost 23% of their tanks and 9% of their personnel.

Nikopol Bridgehead, 31 January-5 February 1944

In July 1944, the German 335th Infantry Division was deployed in a fortified defensive posture at the Nikopol Bridgehead on the Dnieper River in the Ukraine. The division, which held a 12 kilometer wide secondary sector, had based its defenses on a well-developed system of field fortifications with a concentration of a great variety of weapons and a large number of explosive and non-explosive obstacles.

Facing the 335th Division was a Soviet rifle corps (designation currently unknown), which had the mission of breaking through the German defenses on the first day of an offensive set to begin on 31 January. Following the breakthrough, the Soviets planned to seize the river crossing at Bol. Lepatikha, thus preventing the evacuation of German units.

The Soviets, however, were unable to follow their plan. Instead of two days, as they had planned, it took them seven days to reach the Dnieper. This was due mainly to the delay effects of the fortifications prepared by the Germans during the two months preceding the Soviet attack. Bad weather, which rendered the roads almost impassable, also slowed the Soviet advance.

The analysis of the operation was divided into two periods: 31 January-3 February, during with the Soviets slowly made their way through the German first defense zone, about four kilometers deep, and 4-5 February, during which the Soviets pursued the Germans, who were disengaging.

Table 3-3(A) presents the engagement outcomes of the historical battle at the Nikopol bridgehead. During the first four days, when the Soviets were fighting inside the German first defense zone, their rate of advance was very small, just 0.50 kilometers per day (a total of 2.00

Table 3-3. The effects of fortifications.
Nikopol Bridgehead, 31 January - 5 February 1944

A. Historical with Fortifications

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	%Cas /km	% Tanks /km
31 Jan-	4	A	25,109	490	0.49	490	6	3	12.50	3	2.00	0.50	2.00	0.98	25.00
3 Feb		D	8,230	85	0.26	85	0	0	0	0				0.52	0
4-5 Feb	2	A	24,619	120	0.24	610	3	0	0	3	4.00*	2.00	6.00	0.12	0
		D	8,145	65	0.40	150	0	0	0	0				0.20	0
Average	1.0	A	24,812	102	0.41		4.00	0.50	12.50		1.00			0.41	12.50
		D	8,175	25	0.31		0	0	0					0.31	0

*Russian attack v. German withdrawal, 4-5 February, after breakthrough of first fortified zone.

B. QJM Replication with Fortified Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	%Cas /km	% Tanks /km
31 Jan-	4	A	25,109	559	0.56	559	6	2	8.33	2	1.84	0.46	1.84	1.22	18,12
3 Feb		D	8,230	109	0.33	109	0	0	0	0				0.72	0
4-5 Feb	2	A	24,550	132	0.27	691	4	0	0	2	4.38*	2.19	6.22	0.12	0
		A	8,121	97	0.60	206	0	0	0	0				0.27	0
Average	1.0	A	24,772	115	0.46		4.50	0.33	7.33		1.04			0.44	0
		D	8,158	34	0.42		0	0	0					0.40	0

*Russian attack v. German withdrawal, 4-5 February, after breakthrough of first fortified zone.

C. Hypothetical Hasty Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	%Cas /km	% Tanks /km
31 Jan-	2	A	25,109	213	0.42	213	6	1	8.33	1	4.14	2.07	4.14	0.20	4.02
1 Feb		D	8,230	69	0.42	69	0	0	0	0				0.20	0
Average	1.0	A	25,002	107	0.43		5.50	0.50	9.09		2.07			0.21	4.39
		D	8,196	35	0.43		0	0	0					0.21	0

kilometers). However, the German command, fearing an envelopment because of Soviet successes in other sectors, ordered the 35th Infantry Division to disengage and withdraw to a second defensive zone closer to the river.

During the German withdrawal to the second defensive zone the Soviet rate of advance accelerated to two kilometers per day or four kilometers for the period (4-5 February). The relative slowness of the Soviet advance may be explained by the fact that German rear guards, deployed in various strongpoints along the Soviet axis of advance, were able to impede Soviet progress significantly. The impassability of the roads in the sector of the Soviet advance was also an important factor in slowing the Soviet advance toward the river.

On average, during the six days of the engagement, the Soviets advanced one kilometer per day, and this despite a considerable superiority in manpower and firepower.

Personnel casualties of the attacker and the defender were relatively low. This could be explained by the fact that in bad weather casualties are invariably lower than they would be in good weather. During the first phase of the Soviet attack (31 January-3 February), the attacker lost 490 men or 0.49% per day; the defender lost 85 men or 0.26% per day. In the second phase (4-5 February), the attacker's casualties, as expected, declined to 120 men or 0.24% per day; the defender's casualties, however, increased to 65 men or 0.40% per day. On average, during the six days of the engagement, the average daily personnel casualties were 102 men or 0.41%; those of the defender were 25 men or 0.31%.

In view of the small number of tanks engaged -- six on the Russian side and none on the German side -- no comment will be made on tank losses in this engagement.

Average percent casualties per kilometer advanced or retreated was 0.41% for the attacker and 0.31% for the defender. Average percent tank losses per kilometer was 12.50% for the attacker; the defender had no tanks.

Table 3-3(B) shows the outcomes of the QJM replication of the engagement at the Nikopol bridgehead. Note that the attacker's average daily advance rate is very close to the historical rate. The attacker's average daily advance rate in the replication is 1.04 kilometers, which exceeds the historical rate by a factor of 1.04. The average daily

personnel casualties in the replication also correspond very closely to the historical averages. In the replication, the attacker's average daily personnel casualties are 115 men or 0.46%; those of the defender are 34 men or 0.42%. Compared to the historical averages, these figures are high by factors of 1.12 and 1.35 respectively -- an insignificant deviation at percentages as low as these. The average daily tank losses of the attacker (the defender had no armor) are 0.33 tanks or 7.33%; these losses are 59% of the historical losses, but, considering the small number of tanks involved, this figure also is insignificant.

Table 3-3(C) shows the outcomes of a hypothetical engagement at the Nikopol bridgehead assuming the Germans were in a hasty defense posture. The computer-generated figure for the attacker's average daily advance shows that the Soviets would have advanced at a rate of 2.07 kilometers, a rate slightly more than twice the historical rate against the fortified defense. Thus, during two days of combat (31 January-1 February), the Soviets would have advanced 4.14 kilometers. This indicates that the Soviets would probably have reached their objective on 4 February, making it impossible for the Germans to evacuate most of their troops -- as they did historically.

The average daily personnel casualties of the attacker were 107 men or 0.43%; those of the defender were 35 men or 0.43%. These figures are greater than the figures for the historical six-day engagement, which includes personnel casualties sustained in two days of combat during the German withdrawal to their second defense zone. However, when a comparison is made of percent casualties per kilometer advanced or retreated for the hypothetical and historical battles, it can be seen that the figures for the hypothetical hasty defense are much smaller. In the hasty defense the average percent casualties per kilometer is 0.21% for the attacker and 0.21% for the defender; these figures are smaller than those for the historical fortified defense by factors of 0.51 and 0.68 respectively. Regarding tank losses, the attacker, against the hypothetical hasty defense, would have lost, on average, 0.50 tanks or 9.09% per day; this figure is 73% of the same figure for average daily tank losses against the fortified defense (12.50% per day).

The Bowling Alley Offensive, 16-19 February 1944

Following the Allied landings at the Anzio beachhead on 22 January 1944 and the failure of the Allies to push out of the beachhead (see the case study for Aprilia), the Germans built up a powerful force surrounding the beachhead. The first of several German attacks against the beachhead forces occurred on 27 January. This attack was followed by almost a month of hard fighting, during which the Allies sought to expand the beachhead further, and the Germans, for their part, attempted to contain and ultimately to eliminate it.

The focus of much of this fighting was a complex of buildings called the Factory, located almost due north of Anzio and the landing beaches. The Factory, situated on gently rising ground near the intersection of the main Anzio-Albano road and a road called the "Bowling Alley," dominated the beachhead in the Aprilia-Padiglione sector and controlled the road network over which armor was forced to operate in the sector.

By the evening of 12 February persistent German attacks in this sector had pushed the British 1st Infantry Division from the Factory, the village of Carroceto, and Buonriposo Ridge to the west. These gains provided the Germans with the key positions from which to mount a full-scale offensive against the main beachhead line.

The German plan was to split the beachhead along the Anzio-Albano road and capture the port of Anzio. To do this the German Fourteenth Army assembled a force of almost 50,000 men and over 200 tanks and other armored vehicles on a narrow, six-and-one-half kilometer attack front. Included in these totals were elements drawn from seven of the nine German divisions present at the beachhead.

Facing this mass, and destined to receive the full force of the main attack, was the US 45th Infantry Division, which relieved the British 1st Division on 15 February, the eve of the German attack. The strength of the 45th Division, plus attached troops, was over 20,500 men. The division occupied a fortified line extending from Buonriposo Ridge on the west to the hamlet of Carano on the east.

At 0600 on the morning of 16 February 452 German guns opened up along the central beachhead front, heralding the impending enemy attack. One half hour later German troops, supported by tanks, issued from the Factory area and began advancing against the left and center of the 45th

Division's front. Less intensive attacks were made at the same time against the division's right.

By direct frontal attack and infiltration, the Germans pressed home the attack, effecting a major penetration of the 45th Division's front along the axis of the Anzio-Albano road, where they advanced two-and-one-half kilometers, before the fire of Allied divisional and corps artillery and naval guns, plus a massive air support effort made by the Mediterranean Allied Tactical Air Force (MATAF), brought the attack to a halt.

The Germans resumed the attack before midnight on the 16th and continued to attack throughout the next morning and well into the afternoon, attempting to expand their salient. But progress was painfully slow, and once again, the Allies brought the full weight of their artillery and airpower to bear decisively on the enemy, causing extensive casualties and breaking up many attacks in mid-course. Nevertheless, the Germans managed to advance two kilometers farther on the 17th.

The events of 18-19 February have been called the crisis of the Bowling Alley battle. The Germans regrouped and assembled a very powerful combined arms team for a supreme effort to effect a breakthrough. The main effort was made at dawn on the 18th by tanks and infantry following the axes of the Anzio-Albano road and the "Bowling Alley." At first the Germans were successful everywhere, but, once again, the impetus of the offensive was broken by Allied artillery fire and massive close air support.

On the 19th, at 0400, the Germans attacked again, making slight advances before being turned back again by Allied artillery fire. US tank destroyers turned back enemy tanks which made repeated efforts down the Anzio-Albano road to breach the final defense line. By noon it was evident that the 45th Division had broken the back of the German effort, and shortly afterward the enemy gave up the attack and went over to the defensive.

The Bowling Alley offensive was the second and greatest of three German attempts to destroy the Allied Anzio beachhead. Initially successful, it bogged down and succumbed finally to the tenacious defense of the Allied infantry, which was decisively supported by air bombing and artillery fire.

The historical outcomes of the Bowling Alley offensive are shown in Table 3-4(A). The average daily personnel casualties of the attacker were 560 men or 1.36%; those of the defender were 467 men or 2.34%. The average daily losses of armored fighting vehicles were 14 vehicles or 8.14% for the attacker and 9.5 vehicles or 9.60% for the defender. The average daily advance of the attacker was 1.52 kilometers. Average percent casualties per kilometer advanced or retreated was 0.89% for the attacker and 1.54% for the defender. Average percent tank losses per kilometer advanced or retreated was 5.36% for the attacker and 6.32% for the defender.

Table 3-4(B) presents the QJM replication of the Bowling Alley offensive. The computer has generated average daily personnel casualty rates and an average daily advance rate that are very close to the historical rates. The computer-calculated average daily personnel casualty rate for the attacker is 1.22% or 90% of the historical rate (1.36%). The same data for the defender shows a computer-generated casualty rate of 2.48% or 6% greater than the historical rate. The replicated average daily tank losses are 13.46% for the attacker and 24.44% for the defender. These figures exceed the historical rates by 60% and 255% respectively. The apparent discrepancies can be accounted for by the peculiar historical circumstances governing the employment of armor in this battle. The Germans massed a substantial number of armored vehicles on their attack front but were unable to deploy this armor as planned because of wet ground, which confined the tanks to the roads (a hoped-for frost did not materialize). Consequently the German tanks attacked piecemeal, in small, road-bound groups. (The largest identified group was 12 tanks.) US armor, likewise, was either road-bound or well dug-in. Thus, although both sides committed substantial amounts of armor during the engagement, armor losses were much lower than normal losses for an engagement of this intensity because neither side was able to use its armor in masses. Average percent personnel casualties per kilometer of advance or retreat correlates very well with the historical figures. The replication shows a figure of 0.82% per kilometer for the attacker or 92% of the historical rate (0.89%) and 1.66% for the defender or 108% of the historical rate (1.54%). The replication average percent tank losses per kilometer of advance or retreat was 9.03% for the attacker and 16.40% for the defender. The rates exceed the historical rates by factors of 1.97 and 2.59 respectively. The reason for this is noted above.

Table 3-4. The effects of fortifications:
Bowling Alley Offensive, 16-19 February 1944

A. Historical Prepared Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
16 Feb	1	A	41,974	358	0.85	358	201	21	10.45	21	2.50	2.50	2.50	0.34	4.18
		D	20,538	207	1.01	207	119	16	13.45	16				0.40	5.38
17 Feb	1	A	41,616	783	1.88	1,141	180	22	12.22	43	2.00	2.00	4.50	0.94	6.11
		D	20,331	257	1.26	464	103	14	13.59	30				0.63	6.80
18 Feb	1	A	40,833	895	2.19	2,036	158	10	6.33	53	1.28	1.28	5.78	1.71	4.57
		D	20,074	1,175	5.85	1,639	89	7	7.87	37				4.57	4.39
19 Feb	1	A	39,938	202	0.51	2,238	148	3	2.03	56	0.30	0.30	6.08	1.70	6.77
		D	18,899	229	1.21	1,868	84	1	1.19	38				4.03	3.97
Average	1	A	41,090	560	1.36		172	14.0	8.14		1.52			0.89	5.36
		D	19,961	467	2.34		99	9.5	9.60					1.54	6.32

B. QJM Replication with Prepared Defense

16-17 Feb	2	A	41,974	1,231	1.47	1,231	201	69	17.16	69	3.36	1.68	3.36	0.88	10.21
		D	20,538	1,062	2.59	1,062	119	56	23.53	56				1.54	14.01
18-19 Feb	2	A	40,743	771	0.95	2,002	132	15	5.68	84	2.60	1.30	5.96	0.73	4.37
		D	19,476	903	2.32	1,965	63	23	18.25	78				1.78	14.04
Average	1	A	41,108	501	1.22		156	21.0	13.46		1.49			0.82	9.03
		D	19,761	491	2.48		81	19.8	24.44					1.66	16.40

C. Hypothetical Mobile-Hasty Defense

16-17 Feb	2	A	41,974	1,007	1.20	1,007	201	56	13.93	56	6.74	3.37	6.74	0.36	4.13
		D	20,538	1,183	2.88	1,183	119	53	22.27	53				0.85	6.61
18-19 Feb	2	A	40,967	705	0.86	1,712	145	15	5.17	71	5.18	2.59	11.92	0.33	2.00
		D	19,355	1,037	2.68	2,220	66	24	18.18	77				1.03	7.02
Average		A	41,256	428	1.04		164	17.8	10.82			2.98		0.35	3.63
		D	19,669	555	2.82		83	19.3	23.19					0.95	7.78

Table 3-4(C) shows the computer-generated outcomes of a hypothetical Bowling Alley offensive, assuming that the US troops were not dug-in but instead employed a mobile-hasty defense. The attacker's advance rate against this posture is an average of 2.98 kilometers per day or an increase by a factor of 1.96 over the advance rate against the historic prepared defense. Thus, the attacker's advance rate almost doubled. It should be noted, however, that a German breakthrough of the beachhead defensive area against a hypothetical hasty-mobile defense is not indicated by the calculated combat power ratio and, therefore, would be unlikely. Historically, too, the Allies would have been able to bring added combat power (naval gunfire, air bombardment, and corps reserves) against any threatened German breakthrough, so although the Germans would have moved faster and farther against the hasty defense, no breakthrough is indicated.

Average daily personnel casualties in the hypothetical case are 1.04% for the attacker, or 76% of the historical rate, and 2.82% for the defender, an increase by 21% over the historical rate. Average daily tank losses in the hypothetical hasty defense posture are 10.82% for the attacker and 23.19% for the defender. The same figures for the historical prepared defense are 8.14% and 9.60%; so the figures for tank losses in the hasty defense show average percent per day losses that are 33% and 240% higher than those for the historical prepared defense. However, a comparison of the average daily tank loss figures for the hasty defense with the same figures for the QJM replication of the prepared defense shows that tank losses in the hasty defense would probably approximate those of the prepared defense.

The average percent casualties per kilometer of advance or retreat shows that an attack against a hypothetical hasty defense at the Bowling Alley would have been cheaper in terms of the ground gained-casualties tradeoff than the historical attack against a prepared defense. In the hasty mode the attacker loses 0.35% personnel per kilometer advanced; the defender loses 0.95% per kilometer retreated. The attacker's average percent personnel loss per kilometer advanced or retreated is just 39% of that for the historical prepared defense; the defender lost men at a rate 62% of that for the prepared mode. The figures for average percent tank losses per kilometer in the hasty defense situation do not compare well with the same figures for the historical prepared defense for the

reasons cited earlier (see p. 35 above) in the explanation for the discrepancy between the historical engagement indicates that if the historical average percent tank loss per kilometer could be accurately generated, the average percent tank loss per kilometer for the hypothetical hasty defense would probably vary from those of the historical prepared defense by factors of from 0.40 to 0.47.

West Wall, 2-7 October 1944

During the first half of September 1944, Allied armies in northeastern France and Belgium continued the pursuit of German forces begun after the Normandy breakout battles in August. With German forces broken, and everywhere in full retreat, the Allied armies encountered only scattered, token resistance; a rapid advance across the German frontier and through the neglected fortified line of the West Wall -- the only formidable obstacle between the Allies and the Rhine River -- became a possibility.

In mid-September, the US First Army faced the West Wall along a line extending from Maastricht in the "Dutch panhandle" in the north to Luxembourg in the south. On 14 September, the First Army's VII and XIX Corps launched an attack in an effort to reach and pass the fortifications before the disorganized German forces on their front could recover and thoroughly man its defenses.

The VII Corps penetrated the first band of the West Wall south of Aachen and advanced against negligible opposition into the second band near Stolberg. The XIX Corps was delayed, however, as German resistance in its zone stiffened. The VII Corps was eventually stopped in the Stolberg Corridor, and, by the time the XIX Corps had fought its way to the West Wall, the Germans had managed to reorganize and reinforce their shattered forces.

Bad weather and logistical difficulties delayed the XIX Corps attack on the West Wall until 2 October. Then the corps attacked to breach the fortifications above Aachen, seize the Roer River crossings some 14.5 kilometers beyond, and cooperate with the VII Corps in the encirclement of Aachen from north and south.

Following a massive air and artillery bombardment, the 30th Infantry Division attacked across the Wurm River in a narrow assault sector opposite Palenberg-Rimburg, below Geilenkirchen. The 30th Division's mission was to make the initial penetration of the fortified area and secure a bridgehead for the following armor of the 2d Armored Division.

The German fortifications in the assault sector consisted of a belt of pillboxes, some three kilometers in depth, supplemented by field fortifications, minefields, antitank ditches and barbed wire obstacles. This pillbox belt abutted and was closely integrated with two major barriers. The first was the Wurm River, an insignificant stream that nonetheless proved a formidable obstacle to armored operations. The second was a railroad line that followed the trace of the Wurm northward out of Aachen. Since the railway had been constructed with numerous cuts and fills, it too was an obstacle to armored forces. An additional important factor contributing to the strength of the defense in the assault sector was the heavy population density of the area encompassed by the pillbox belt. The terrain, generally rolling, was dotted with dozens of strongly-built industrial towns and workers' barracks, factories, and coal mines. Here and there behind the main pillbox line enormous slag piles and pit head structures of coal mines served as infantry positions and artillery observation posts. Since the mines were often interconnected by horizontal underground shafts, they were potentially very strong combat positions, easily reinforced or evacuated.

The defense of the assault sector was the responsibility of the German LXXXI Corps, which, although its disposition was heavily concentrated toward the US VII Corps threat below Aachen, had adequate strength at the XIX Corps point of attack. The major deficiencies of the defense were the shortages of heavy weapons and antitank means and the lack of a mobile reserve striking force.

The XIX Corps attack on D-Day was successful to the extent that the 30th Division infantry established a small bridgehead east of the Wurm, but the assault regiments were completely without armored support at the end of the day's fighting because the "expedient bridges" intended to facilitate the advance of the supporting armor had either become bogged down in the marshy meadows bordering the Wurm, or the bulldozers shunting them into position themselves became stuck in the mud. However, two treadway bridges and a Bailey bridge were installed during the night of 2-3 October, and the way was opened for the infantry's armor to reinforce it, and for the commitment of CCB, 2d Armored Division.

On 3 October the assault was renewed, major objectives being the expansion of the 30th Division's bridgehead, the reduction of strong German resistance in the Rimburg Woods, and the capture of the town of Uebach and the high ground beyond the town to the north and northeast. The woods were cleared, and a foothold was seized in Uebach, but German resistance stiffened, and the toll of American casualties, especially to the well-directed enemy artillery fire, mounted.

On 4 October the attacker's objectives remained unchanged. The Germans, however, launched several counterattacks, most of which were broken up by artillery fire. The 30th Division infantry made little progress, since its attack was delayed by German artillery fire, but CCB managed short advances north and northeast of Uebach, rolling up portions of the pillbox belt.

On the 5th, infantry fighting in Uebach continued, and the town was finally cleared. Preparations were advanced for the final attack along the flank of the pillbox belt from north to south. To the north of Uebach, meantime, CCB continued to expand the penetration toward the high ground along the main Geilenkirchen-Aachen road.

The US infantry advance resumed on 6 October, and a German strongpoint at the military barracks east of Uebach was reduced. Another strongpoint at Herbach was captured, and German resistance in the 30th Division sector began to collapse. In the northern sector, CCB, too, continued its advance, largely securing the northern flank of the penetration. While these advances were proceeding, CCA, 2d Armored Division, crossed the Wurm and assembled at dark one kilometer east of Uebach.

On 7 October the XIX Corps penetration of the first band of the West Wall was completed, and the exploitation or breakthrough phase of the operation began. CCA joined the 30th Division infantry in a drive southeast across open country toward Baeswiler and Alsdorf, and, as German resistance crumbled, 1,138 prisoners were taken. In the north, CCB adjusted its front and organized its gains of the previous day. These advances completed the XIX Corps penetration of the first band of the West Wall.

In the days that followed, the XIX Corps continued its drive south and east, and on 16 October, after more hard fighting punctuated by desperate German counterattacks, the encirclement of Aachen was completed

when the XIX Corps joined the VII Corps east of that ancient city of emperors.

Table 3-5(A) shows the historical outcomes of the six days' combat at the West Wall in the US XIX Corps sector during 2-7 October 1944. The average daily personnel casualties of the attacker during this period were 246 men or 0.76%; those of the defender were 603 men or 3.16%. It should be noted that 2,860 (79%) of the total 3,616 casualties suffered by the defending German LXXXI Corps were prisoners of war. The average daily armor losses of the combatants were 13 tanks or 4.17% for the attacker and 8 tanks or 22.22% for the defender. The average daily advance of the attacker was 1.26 kilometers. Average daily personnel casualties per kilometer advanced or retreated were 0.60% for the attacker and 2.51% for the defender. Average daily tank losses per kilometer advanced or retreated were 3.31% for the attacker and 17.63% for the defender.

Table 3-5(B) shows the computer-generated engagement outcomes data for the QJM replication of the XIX Corps attack on the West Wall. The computer has calculated the attacker's average daily personnel casualties at 0.83% or 9% greater than the historical rate (0.76%). The defender's average daily personnel casualties were calculated at 1.41%, a figure just 45% of the historical rate (3.16%). The source of the discrepancy would appear to lie in the large number of prisoners taken in the operation. An examination of the relevant records reveals that the number of German prisoners taken each day during the engagement increased gradually during the period 2-6 October and then radically on the 7th, the day of the breakthrough. This data is shown in Table 3-6. Table 3-6, interpreted in the light of the engagement record, indicates that the QJM has probably replicated German battle casualties, including prisoners taken under normal circumstances during the engagement, quite well. Prisoners taken under extraordinary circumstances in this engagement fall into two categories:

1. Those prisoners taken in the mass surrender that took place after US armor and infantry broke free of the first band of fortifications and began to exploit the breakthrough in the less heavily fortified area between Uebach and Alsdorf.

2. Those taken when pillboxes were reduced or captured. Although strictly forbidden to do so, German troops manning field fortifications

TABLE 3-5. THE EFFECTS OF FORTIFICATIONS: WEST WALL, 2-7 OCTOBER 1944

A. Historical with Fortifications

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	%Cas /km	% Tanks /km
2 Oct	1	A	25,345	205	0.81	205	131	1	0.76	1	1.00	1.00	1.00	0.81	0.76
		D	10,844	238	2.19	238	14	3	21.43	3				2.19	21.43
3 Oct	1	A	32,268	202	0.63	407	302	3	0.99	4	0.90	0.90	1.90	0.70	1.10
		D	16,399	381	2.32	619	41	4	9.76	7				2.58	10.84
4 Oct	1	A	32,066	450	1.40	857	299	8	2.68	12	0.50	0.50	2.40	2.80	5.36
		D	15,612	357	2.29	976	50	5	10.00	12				4.58	20.00
5 Oct	1	A	31,616	158	0.50	1,015	291	25	8.59	37	1.00	1.00	3.40	0.50	8.59
		D	23,035	660	2.87	1,636	45	10	22.22	22				2.87	22.22
6 Oct	1	A	36,336	272	0.75	1,287	438	30	6.85	67	1.13	1.13	4.53	0.66	6.06
		D	24,686	716	2.90	2,352	41	18	43.90	40				2.57	38.85
7 Oct	1	A	36,064	190	0.53	1,477	408	12	2.94	79	3.00**	3.00	7.53	0.18	0.98
		D	23,970	1,264	5.27	3,616*	23	9	39.13	49				1.76	13.04
Average	1.0	A	32,283	246	0.76		312	13	4.17		1.26			0.60	3.31
		D	19,091	603	3.16		36	8	22.22					2.51	17.63

* German casualties include 2,860 POW.

** U.S. attack against German prepared defense after breakthrough of first fortified zone.

B. QJM Replication with Fortified Defense

2 Oct	1	A	25,345	276	1.09	276	131	17.00	12.98	17	0.56	0.56	0.56	1.95	23.18
		D	10,844	127	1.17	127	14	1.00	7.14	1				2.09	12.75
3 Oct	1	A	32,197	438	1.36	714	286	43.00	15.03	60	0.82	0.82	1.38	1.66	18.33
		D	16,510	340	2.06	467	43	8.00	18.60	9				2.51	22.68
4 Oct	1	A	31,759	269	0.85	983	243	14.00	5.76	74	0.56	0.56	1.94	1.52	10.29
		D	16,576	156	0.94	623	48	2.00	4.17	11				1.68	7.45
5 Oct	1	A	31,490	196	0.62	1,179	229	8.00	3.49	82	0.67	0.67	2.61	0.93	5.21
		D	24,200	369	1.52	992	46	5.00	10.87	16				2.27	16.22
6 Oct	1	A	36,172	217	0.60	1,396	351	12.00	3.42	94	0.67	0.67	3.28	0.90	5.11
		D	26,142	386	1.48	1,378	47	6.00	12.77	22				2.21	19.10
7 Oct	1	A	35,955	203	0.56	1,599	339	11.00	3.24	105	2.73*	2.73	6.01	0.26	1.55
		D	25,756	321	1.25	1,699	41	3.00	7.32	25				0.65	5.50
Averages	1.0	A	32,153	267	0.83		263	17.50	6.65		1.00			0.83	6.65
		D	20,005	283	1.41		40	4.16	10.40					1.41	10.40

*U.S. Attack v. German prepared defense after breakthrough of first fortified zone.

C. Hypothetical Mobile-Hasty Defense

2 Oct	1	A	25,345	258	1.02	258	131.0	19.0	14.50	19	4.72	4.72	4.72	0.22	3.07
		D	10,844	166	1.53	166	14.0	1.0	7.14	1				0.32	1.51
3 Oct	1	A	32,215	467	1.45	725	284.0	58.0	20.42	77	4.19	4.19	8.91	0.35	4.87
		D	16,471	302	1.83	468	43.0	5.0	11.63	6				0.44	2.78
Averages	1.0	A	28,780	363	1.26		208.0	38.5	18.51		4.46			0.28	4.15
		D	13,658	234	1.71		28.5	3.0	10.52					0.38	2.36

Table 3-6.

GERMAN PRISONERS TAKEN BY US FORCES AT THE WEST WALL, 2-7 OCTOBER 1944

Date	Prisoners Captured By...				
	30th ID	2d AD	Atchd.Trps.	Total	Cum
2 Oct. 44	112	--	--	112	112
3 Oct. 44	255	--	--	255	367
4 Oct. 44	125	106	--	231	598
5 Oct. 44	117	417	--	534	1,132
6 Oct. 44	264	325	1	590	1,722
7 Oct. 44	794	325	19	1,138	2,860
Totals	1,667	1,173	20	2,860	

covering pillboxes invariably abandoned the field fortifications and sought shelter inside the pillboxes when they were taken under heavy and accurate US artillery fire. Thus, when pillboxes were reduced or captured, the haul of prisoners often exceeded expectations, since it usually included many more troops than the normal pillbox garrisons.

The average daily tank losses in the replication were 6.65% for the attacker and 10.40% for the defender. This compares favorably with the historical average daily tank losses, especially considering the fact that the US armor was largely unable to cross the Wurm and engage on D-Day and was not really committed en masse until D+1. The vulnerability of US armor to enemy antitank means was, therefore, practically nil on D-Day; indeed, the historical record shows that the US forces lost only one tank on D-Day -- again primarily because it was largely impossible for the armor actually to get to the front. The calculated average daily German tank losses are just 49% of the historical average daily tank losses for the defender, a not unreasonable figure when it is recalled that, historically, the Germans were forced by circumstances to commit their armor piecemeal in small groups in support of desperate counterattacks.

The computer-generated daily advance rate in the replication is 1.00 kilometer or 79% of the historical average daily advance rate (1.26 kilometers). In sum, the QJM replication of the XIX Corps assault on the West Wall has very faithfully reproduced the historical engagement outcomes of a very complex military operation.

Table 3-5(C) shows the computer-calculated engagement outcomes of a hypothetical engagement at the West Wall assuming that the West Wall did not, in fact, exist and that the Germans opposed to the US XIX Corps were in a hasty-mobile defensive posture. As the table shows, the attacker's average daily advance rate against a hypothetical hasty defense would have been 4.46 kilometers -- an increase by a factor of 3.54 over the average daily advance rate against the historical fortified defense (1.26 kilometers). At this rate the US forces would have achieved a breakthrough of the German defensive zone on D+1. The results of such a breakthrough might well have had a decisive bearing on the outcome of the war, because it is unlikely that, with the commitment of the 2d Armored Division, the US attack could have been stopped short of the Roer River or, quite possibly, the Rhine. Indeed, viewed strategically,

and positing a breakthrough and disruption of German defenses all along the US First Army front in October 1944, a "race to the Rhine" might have developed, and the war might have ended in the West in the autumn of 1944.

The ability of the defender to react to a main effort attack made on a narrow sector of a broad front is affected by the extent and quality of the fortifications available to the defender. The average strength of the defender in the hypothetical West Wall example is 13,658 men -- a strength which reflects the ability of the Germans to react over a 48-hour period by committing only limited local reserves. The average strength of the defender in the historical engagement was 19,091 men, an increase of 5,433 men over the manpower total available in the hypothetical hasty defense. This number includes personnel drawn from corps reserves. Theater reserves, drawn from as far away as the Belfort Gap and Luxembourg (400 kilometers), did not begin to arrive in the operational area until 10 October. Historically, the effect of the commitment of German corps reserves was to slow and contain the US penetration until 7 October, when the breakthrough occurred; the effect of the commitment of German theater reserves was to slow and then stop the US breakthrough at the second band of West Wall fortifications. Neither effect would have been possible had not the West Wall fortifications existed.

In the hypothetical example the average daily personnel casualties of the attacker are 363 men or 1.26%, those of the defender are 234 men or 1.71%. Thus, compared to the historical fortified defense, the attacker's average daily personnel casualties have increased by a factor of 1.66, while those of the defender have declined by a factor of 0.54. Note, however, that the average percent personnel casualties per kilometer advanced or retreated has declined significantly for both the attacker and the defender in the hypothetical posture as compared to the fortified posture. The figure for the attacker has declined from 0.60% to 0.28%, a reduction by a factor of 0.47; that for the defender has declined from 2.51% to 0.38%, a reduction by a factor of 0.15.

The average daily tank losses of the hypothetical example are 18.51% for the attacker and 10.53% for the defender. These figures, compared to the same figures for the historical fortified defense, follow the same

pattern generally as the figures for the average daily personnel casualties of both sides -- the attacker's average daily tank losses have increased by a factor of 4.44, while those of the defender have decreased by a factor of 0.47. However, average percent tank losses per kilometer show that the attacker's loss has increased slightly from 3.31% in the historical fortified defense to 4.15% in the hasty defense, while the defender's loss has declined dramatically from 17.63% to 2.36%.

Seelow Heights, 16-17 April 1945

In the spring of 1945 German forces in Brandenburg were prepared to resist an imminent Soviet offensive toward Berlin from a hurriedly-prepared but powerful system of field fortifications sited generally along the west bank of the Oder River. The Seelow Heights sector, east of Berlin, was especially well fortified, since it was considered by the Germans to be the key to the approach to their capital.

In mid-April the German 303d Infantry Division's 303d Infantry Regiment, together with its supporting elements, was deployed in a two kilometer wide sector of the Seelow Heights area just to the east of the city of Seelow. The German fortifications were deeply-echeloned and consisted of numerous full-profile trenches, communications trenches, bunkers, pillboxes, barbed wire entanglements, minefields, and antitank ditches. The fortifications were enhanced by the terrain, which included the high bank (scarp) of the dry river bed of the Old Oder River. This escarpment rises from 40 to 50 meters above the Oder Valley (the Old Oder river bed) at an angle of from 30 to 40 degrees.

The total strength of the defending German force was nearly 4,000 men and five tanks.

Facing the Germans was the Soviet 57th Guards Rifle Division of the IV Guards Rifle Corps and attached artillery, armor, and multiple rocket launcher units. Altogether, the Soviet force numbered over 13,000 men and 62 tanks. Additionally, an independent tank brigade (65 tanks) was available to the Soviet commander as a ready reserve.

On 14 April, two days before the start of the main offensive, the Soviets opposite Seelow attacked German forward positions hemming their bridgehead on the west bank of the Oder. This operation brought the Soviets through the German covering zone and abreast of the German main

defensive area by 1500 hours on 15 April. The main offensive was set to begin at 0600 hours on 16 April.

The Soviet command expected to break through the German main defenses and advance 15 to 20 kilometers during the first day of the offensive. These Soviet projections proved to be too optimistic. During the first 24 hours of the offensive the 57th Guards Rifle Division advanced only two kilometers, being unable, despite many efforts, to negotiate all the fortifications and surmount the escarpment.

On the 17th the Soviets added the reserve tank brigade to the attacking force and resumed the attack. During the first seven hours the attackers advanced only 250 meters. Then, after some neighboring Soviet units broke through the defenses on the flanks of the 303d Infantry Regiment, the Germans, fearing envelopment, disengaged and began a rapid withdrawal. For the rest of the day, the Soviets continued to advance without meeting serious opposition.

Table 3-7(A) shows the outcomes of the historical engagement at Seelow Heights. The average daily personnel casualties were 237 men or 1.74% for the attacker; those of the defender were 76 men or 2.05%. The average daily tank losses were 27 tanks or 34.62% for the attacker and 1.5 tanks or 42.86% for the defender. The attacker's average daily advance rate was 1.13 kilometers. The average percent personnel casualties per kilometer was 1.54% for the attacker and 1.81% for the defender. The average percent tank loss per kilometer was 30.64% for the attacker and 37.93% for the defender.

Table 3-7(B) shows the engagement outcomes of the QJM replication of the battle at Seelow Heights. The average daily personnel casualties are 233 men or 1.71% for the attacker and 51 men or 1.36% for the defender. These figures compare favorably with the relevant historical figures, although the figure for German personnel casualties exceeds the historical figure by a factor of 1.51. This is a negligible difference considering the small size and the few casualties of the defending force. The average daily tank losses of the attacker are 33 tanks or 51.56%; those of the defender are 0.5 tanks or 11.11%. The figure for the attacker is reasonably close to the historical tank loss rate (exceeding it by a factor of 1.49), while the figure for the defender in both cases is so small that comparison would be pointless. The average daily advance rate is 0.71 kilometers, which is 63% of the historical rate. The average percent personnel casualties

Table 3-7. The effects of fortifications:
Seelow Heights, 16-17 April 1945

A. Historical Fortified Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
16 Apr	1	A	13,293	420	3.16	420	62	33	53.23	33	2.00	2.00	2.00	1.58	26.62
		D	3,782	140	3.70	140	5	3	60.00	3				1.85	30.00
17 Apr	0.3	A	13,983	54	1.32*	474	94	21	76.63*	54	0.25	0.86*	2.25	1.53*	89.10*
		D	3,642	11	1.04	151	2	0	0.0	3				1.21	0.00
Average	1	A	13,638	237	1.74		78	27	34.62		1.13			1.54	30.64
		D	3,712	76	2.05		3.5	1.5	42.86					1.81	37.93

B. QJM Replication with Fortified Defense

16 Apr	1	A	13,293	421	3.17	421	62	61	98.39	61	0.89	0.89	0.89	3.56	110.55
		D	3,782	88	2.33	88	5	1	20.00	1				2.62	22.47
17 Apr	0.3	A	13,982	45	1.10*	466	66	5	25.98*	66	0.16	0.52*	1.41	2.12	49.96
		D	3,694	14	1.30	102	4	0	0.0	1				2.50	0.00
Average	1	A	13,638	233	1.71		64	33	51.56		0.71			2.41	72.62
		D	3,738	51	1.36		4.5	0.5	11.11					1.92	15.65

C. Hypothetical Hasty-Mobile Defense

16 Apr	1	A	13,293	155	1.17	155	62	14	22.58	14	10.37	10.37	10.37	0.11	2.18
		D	3,782	132	3.49	132	5	1	20.00	1				0.34	1.93

* Projected over 24 hours.

per kilometer is 2.41% for the attacker and 1.92% for the defender. The average percent tank casualties per kilometer is 76.62% for the attacker and 15.65% for the defender.

Table 3-7(C) shows the computer-calculated outcomes for a hypothetical case in which the Germans at Seelow Heights were considered to be in a hasty-mobile posture instead of a fortified posture. The average daily personnel casualties are 155 men or 1.17% for the attacker and 132 men or 3.49% for the defender. Thus, compared to the historical fortified defense, the attacker's average daily personnel casualties would be lower (by a factor of 0.67), while those of the defender would be higher (by a factor of 1.70). The average daily tank losses are 14 tanks or 22.58% for the attacker and one tank or 20.00% for the defender. Compared to the fortified defense, the tank losses of both the attacker and the defender would have fallen: that of the attacker by a factor of 0.65 and that of the defender by a factor of 0.47. The average daily advance rate is 10.37 kilometers, a rate 9.18 times faster than the advance rate against the fortified defense. This shows that against the hasty defense the Soviets would have broken through the German defensive area very quickly and taken Seelow, opening the way for the commitment of their tank armies into the "operational space" for a rapid thrust toward Berlin. Average percent casualties per kilometer in the hasty variant are 0.11% for the attacker and 0.34% for the defender; these figures represent decreases by factors of 0.07 and 0.19 respectively, compared to the same figures for the fortified posture. Average percent tank losses per kilometer are 2.18% for the attacker and 1.93% for the defender, decreases by factors of 0.07 and 0.03 respectively compared to the same figures for the fortified posture.

Suez Canal (North), 6 October 1973

The Israeli defensive system on the east bank of the Suez Canal, the Bar Lev Line, was initially constructed as a line of fortified observation posts or strongpoints to protect observers, challenge Egyptians trying to cross the canal, and provide a useful ground base for armored maneuver. It was never thought of, and could not be remotely compared to, such well-known systems of fortification as the Maginot Line, the West Wall, or the Mannerheim Line.

The strength of the Bar Lev position lay principally in the availability of armor units, supported by artillery and aircraft, for counterattacks, and only incidentally and locally in the formidable protection of each strongpoint.

The Israeli defenses consisted of two major obstacles. The first was the canal itself, a continuous water-filled channel about 200 meters wide and some 18 meters deep. The second was the system of fortifications along the east bank, and the mobile reserves deployed to their rear. Distributed along the canal, in the area of the Egyptian Second Army's offensive (from the Mediterranean coast in the north to the southern edge of the Great Bitter Lake in the south), were twelve widely-separated strongpoints. Between them the Israelis had sown minefields.

The Israeli concept of defending the Bar Lev Line was based on deploying in that sector two separate front-line units with totally different missions. Some 450 men of the Etzioni Reserve Infantry Brigade from Jerusalem garrisoned the strongpoints. Their mission, in addition to observation, was to turn back or delay any Egyptian advance eastward. It should be noted, and subsequent events proved it very important, that the men of the Etzioni Brigade were reservists, who replaced regular army units shortly before the outbreak of the war. The reservists were, on the whole, not very well acquainted with the defensive system. Behind the strongpoint garrisons and distributed along the so-called Artillery Road some 10 kilometers east of the canal were elements of a regular armored brigade and ten to twelve artillery batteries. In the event of an Egyptian attack, the task of the armor was to advance quickly to prepared positions in the vicinity of the canal, counterattack any Egyptian units which were able to cross, and push them back into the canal.

Facing the Israelis in the northern sector of the Suez Canal was the Egyptian Second Army. On the day of the assault, the forward elements of this army -- those committed to the assault -- were about 24,500 men strong. This force had only two companies of amphibious tanks (17 tanks).

During the initial phase of the engagement, which lasted ten hours, the Egyptians crossed the canal at several points and advanced some 800 meters. However, it should be noted that this advance was only in areas between the strongpoints. During the described period, only one

strongpoint was captured; the others offered strong resistance and considerably delayed the Egyptian advance. Additionally, the Egyptians had to commit a large number of troops to block and assault strongpoints.

Table 3-8(A) shows the historical outcomes of the Egyptian assault across the Suez Canal in the northern sector. The attacker's average daily advance rate (projected over 24 hours) was 2.00 kilometers. The casualties of the attacker were 200 men or 0.82%; those of the defender were 130 men or 2.92%. The attacker's tank losses were two tanks or 11.76%; those of the defender were 35 tanks or 52.24%. Average percent casualties per kilometer advanced or retreated was 0.98% for the attacker and 3.48% for the defender. Average percent tank losses per kilometer was 14.00% for the attacker and 62.19% for the defender.

Table 3-8(B) shows the computer-generated outcomes for the QJM replication of the Suez Canal (North) assault. The attacker advanced 0.91 kilometers in ten hours (2.16 kilometers projected over a 24-hour period). This figure correlates very well with the historical advance, being larger by a factor of only 1.08. The attacker's personnel casualties have been calculated at 177 men or 0.72%; those of the defender are 131 men or 2.94%. These figures correspond with the same historical figures by factors of 0.88 and 1.01 respectively. The attacker's tank losses are three tanks or 17.65%; those of the defender are 17 tanks or 25.37%. The figure for the attacker, representing a difference of just one more tank loss than in the historical engagement, is quite accurate. The figure for the defender is smaller than the historical figure by a factor of 0.49. This apparent discrepancy may be explained by the much higher than average Israeli tank losses incurred against Egyptian infantry squads armed with the man-portable Sagger antitank missile, which was being used for the first time in Middle Eastern warfare. The attacker's percent casualties per kilometer is 0.79%; that of the defender is 3.23%. These figures correspond with the same historical figures by factors of 0.81 and 0.93 respectively. The attacker's percent tank loss per kilometer is 19.40%; that of the defender is 27.88%. These figures compare with the same historical figures by factors of 1.39 and 0.49.

Table 3-8(C) shows the engagement outcomes of the alternate hypothetical situation, assuming the Israelis organized only a hasty defense. The QJM-generated figures show that the Egyptians would have advanced 2.40 kilometers in the ten-hour engagement (5.75 kilometers projected over 24 hours). This

Table 3-8. The effects of fortifications:
Suez Canal (North), 6 October 1973

A. Historical Prepared-Fortified Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
6 Oct	0.42	A	24,490	200	0.82	200	17	2	11.76	2	0.84	2.00*	0.84	0.98	14.00
		D	4,455	130	2.92	130	67	35	52.24	35				3.48	62.19

B. QJM Replication with Prepared-Fortified Defense

6 Oct	0.42	A	24,490	177	0.72	177	17	3	17.65	3	0.91	2.16*	0.91	0.79	19.40
		D	4,455	131	2.94	131	67	17	25.37					3.23	27.88

C. Hypothetical Hasty Defense

6 Oct	0.42	A	24,490	199	0.81	199	17	5	29.41	5	2.4	5.75*	2.4	0.34	12.25
		D	4,455	131	2.94	131	67	29	43.28	29				1.23	18.03

* Projected over 24 hours.

is an increase by a factor of 2.86 over the advance rate for the historical engagement. It should be noted that, in both cases, the Suez Canal, a unique water barrier, considerably affected rates of advance and personnel casualties and tank losses.

The attacker's personnel casualties are 199 men or 0.81%; those of the defender are 131 men or 2.94%. These figures are very close to the same figures for the historical engagement, almost coinciding. The attacker's tank losses are five tanks or 29.41%; those of the defender are 29 tanks or 43.28%. These figures are also close to the same figures for the historical engagement; the attacker's tank losses have increased by three tanks (a factor of 2.50), while those of the defender have decreased by six tanks (a factor of 0.83), compared to the historical fortified defense.

The real difference between the historical engagement and the alternate hypothetical example, then, must be sought in the advance rate, and the figures for percent casualties per kilometer and percent tank losses per kilometer. In the hypothetical example the attacker's percent casualties per kilometer is 0.34%; that of the defender is 1.23%. These figures show that the percent casualties per kilometer in the hasty example would have declined for both the attacker and the defender by a factor of 0.35 compared to the historical fortified defense. The percent tank losses per kilometer is 12.25% for the attacker and 18.03% for the defender. Compared to the same historical figures, these figures show that the per kilometer tank losses of the attacker and the defender would have declined by factors of 0.88 and 0.29 respectively in the alternate hasty example.

In conclusion, the Bar Lev fortification system fulfilled its primary purpose, which was to slow the Egyptian advance, preventing the Egyptians from penetrating deeply into the Sinai and making it easier for Israeli reserves to be mobilized and committed to contain the attacker in a relatively shallow bridgehead.

Ahmadiyeh, 6-7 October 1973

The Golan Heights region of western Syria was occupied by the Israelis during the 1967 Arab-Israeli War. Between 1967 and 1973 the Israelis constructed a formidable system of fortifications along the eastern edge

of the Golan plateau. Just to the west of the ceasefire line (known as the "Purple Line"), the Israelis built an antitank ditch four to six meters wide and about four meters deep. Behind it was a system of bunkers, concrete observation posts, strongpoints, and minefields.

On the eve of the 1973 October War the Ahmadiyeh sector (just north of Kuneitra) was defended by elements of the Israeli 7th Armored Brigade and elements of the 188th (Barak) Armored Brigade, a total of over 5,000 men. Deployed opposite the Israelis was the Syrian 7th Infantry Division, which, with attachments, had nearly 23,000 effectives. The mission of the Syrian force was to break through the Israeli defenses, destroy the defenders, and advance to the old Syrian-Israeli border -- all in the first 24 hours of the offensive.

The Syrians launched their attack at 1405 hours on 6 October. Soon after that, the leading elements -- infantry and armor -- reached the antitank ditch. But, as a result of confusion and poor planning (the bridging equipment was well in the rear of the advance elements), the Syrians were unable to cross the ditch as speedily as planned. It became necessary to use shovels to fill the ditch. While this was going on, the Israelis poured in a severe fire, which caused many casualties.

Thus the Syrian attack became bogged down just west of the Purple Line. Even after the division succeeded in laying bridges across the ditch, most of its elements remained pinned down and could advance no further.

Table 3-9(A) shows the outcomes of the historical engagement at Ahmadiyeh. During the 34-hour operation, the Syrians advanced 0.80 kilometers, an average daily advance of 0.57 kilometers. The average daily personnel casualties of the attacker were 876 men or 3.93%; those of the defender were 212 men or 3.76%. The average daily tank losses of the attacker were 96 tanks or 96.97%; those of the defender were 21 tanks or 29.58%. The average percent personnel casualties per kilometer advanced or retreated (projected over one kilometer) was 6.89% for the attacker and 6.60% for the defender. The average percent tank losses per kilometer (also projected over one kilometer) was 170.12% for the attacker and 51.90% for the defender.

Table 3-9. The effects of fortifications:
Ahmadiyeh, 6-7 October 1973

A. Historical Prepared-Fortified Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
6-7 Oct	1.42	A	22,750	1,234	3.85	1,234	147	135	65.31	135	0.80	0.57	0.80	6.75	114.58
		D	5,745	298	3.69	298	78	30	26.92	30				6.47	47.23
Average	1.0	A	22,312	876	3.93		99	96	96.97		0.57			6.89	170.12
		D	5,639	212	3.76		71	21	29.58					6.60	51.90

B. QJM Replication with Prepared-Fortified Defense

6-7 Oct	1.42	A	22,750	531	1.65	531	147	82	39.46	82	1.09	0.77	1.09	3.30	51.19
		D	5,745	137	1.68	137	78	16	14.56	16				2.18	18.91
Average	1.0	A	22,561	377	1.67		118	58	49.15		0.77			2.17	63.83
		D	5,696	97	1.70		73	11	15.07					2.21	19.57

C. Hypothetical Mobile-Hasty Defense

6-7 Oct	1.42	A	22,750	328	1.02	328	147	51	24.63	51	7.37	5.19	7.37	0.19	4.74
		D	5,745	224	2.77	224	78	26	23.67	26				0.53	4.56
Average	1.0	A	22,633	233	1.03		129	36	27.91		5.19			0.20	5.38
		D	5,665	159	2.81		68	19	27.94					0.54	5.38

Table 3-9(B) shows the outcomes of the QJM replication of Ahmadiyeh. The average daily advance rate is 0.77 kilometers, which exceeds the historical figure by a factor of 1.35. The average daily personnel casualties of the attacker are 377 men or 1.67%; those of the defender are 97 men or 1.70%. These figures are smaller than the relevant historical figures by factors of 0.42 and 0.45 respectively. The average daily tank losses of the attacker are 58 tanks or 49.15%; those of the defender are 11 tanks or 15.07%. These figures are also smaller than the relevant historical figures by factors of 0.51 each.

Table 3-9(C) shows the computer-generated outcomes of a hypothetical battle at Ahmadiyeh assuming the Israelis had organized only a hasty defense. The attacker's average daily advance rate is 5.19 kilometers, that is almost ten times greater than the historical rate. The average daily personnel casualties are 233 men or 1.03% for the attacker and 159 men or 2.81% for the defender. These figures are smaller than those of the historical engagement by factors of 0.26 and 0.75 respectively. The average daily tank losses are 36 tanks or 27.91% for the attacker and 19 tanks or 27.94% for the defender. These figures are smaller than the same figures for the historical engagement by factors of 0.29 and 0.94 respectively. The average percent personnel casualties per kilometer is 0.20% for the attacker and 0.54% for the defender. These figures are smaller than the same figures for the historical fortified defense by factors of 0.03 and 0.08 respectively. The average percent tank losses per kilometer is 5.38% for both the attacker and the defender. These figures are smaller than the same figures in the historical engagement by factors of 0.03 and 0.10 respectively.

A comparison of the outcomes for the hypothetical hasty defense with those of the historical fortified defense shows that against a hasty defense the Syrians would have easily broken through the Israeli defenses and reached their planned objectives. Indeed, an operational analysis of the entire Golan Heights battle leads inevitably to the conclusion that the Israeli fortifications were instrumental in delaying the Syrian advance in the southern and central sectors and in stopping it altogether at Ahmadiyeh. Had these fortifications not existed, in all probability the Syrians would have overrun the Israeli defenders and reached the old Syrian-Israeli border, if not Israel proper, before substantial Israeli

reserves could have arrived. Thus the war probably would have had a very different outcome

EXAMPLES OF HASTY-MOBILE DEFENSES

Aprilia, 25-26 January 1944

In a move to outflank the German Gustav Line defenses, the US Fifth Army's VI Corps, commanded by Major General John P. Lucas, made an amphibious landing at Anzio-Nettuno on 22 January 1944. The landing achieved surprise and consequently was virtually unopposed by the scattered German units in the beachhead area. However, rather than driving inland to the commanding hill mass of the Colli Laziali (Alban Hills) while German resistance was weak, General Lucas elected to consolidate the beachhead and await reinforcements. Given time to recover, the Germans rushed their own reinforcements to the beachhead area and prepared to resist seriously any further Allied advances.

In the process of consolidation, the British 1st Infantry Division had the mission of advancing the beachhead line to the town and railroad junction of Campoleone, which was situated about 20 kilometers north of Anzio along the Anzio-Albano road. This objective would serve as a strategic jump-off point for any future attack on the Colli Laziali. The immediate objective, however, was Aprilia, a hamlet located on the Anzio-Albano road about five kilometers south of Campolene. The major feature of the Aprilia area was a complex of buildings called the "Factory," a model farm which dominated the surrounding terrain and would be the scene of continuous fighting throughout the Anzio campaign. Aprilia was defended by elements of the German 3d Panzer Grenadier Division.

On 25 January the 1st Division began its drive on Aprilia, attacking northward along the axis of the Anzio-Albano road. In this drive the British infantry was supported by a squadron of the 46th Royal Tanks, one medium and two field regiments of artillery, and naval gunfire. The British attack was successful, and, by the end of the first day, the Germans had been driven from the vital Factory complex. On the 26th, after repelling a strong German counterattack at the Factory, the 1st Division resumed its attack and pushed a narrow, finger-like salient over two kilometers further northward toward Campoleone.

In this advance the 1st Division had received no air support. German Ju-88 bombers flew 28 sorties in support of the 3d Panzer Grenadier Division.

Table 3-10(A) shows the historical outcomes of the engagement at Aprilia. The attacker's advance rate, averaged over two days, was 2.40 kilometers per day. The average daily personnel casualties of the attacker were 124 men or 0.64%; those of the defender were 49 men or 0.73%. The average percent casualties per kilometer advanced or retreated were 0.27% for the attacker and 0.30% for the defender. The average daily tank losses of the attacker were 3.50 tanks or 2.89%; those of the defender were two tanks or 4.44%. The average percent tank loss per kilometer advanced or retreated was 1.20% for the attacker and 1.85% for the defender.

Table 3-10(B) shows the QJM replication of this engagement. In each category the computer-generated data corresponds quite closely with the historical outcomes. The QJM replications for attacker's and defender's casualties show average percent per day rates of 0.62% and 0.76% respectively, which correlate very closely with the historical rates. The QJM replications for attacker's and defender's tank losses show average percent per day rates of 3.72% and 3.33% respectively, which correspond quite closely to the historical tank losses. Since the QJM has also replicated the British advance rate quite well, generating an average daily advance of 2.81 kilometers (within 17% of the historical rate) this engagement shows a notable degree of relative correspondence between historical outcomes and QJM computer-generated data.

Table 3-10(C) shows the QJM-generated results of the same engagement assuming that the Germans had fortified the Aprilia-Factory complex and the rising ground on the approaches to Campoleone along the Anzio-Albano road. In this hypothetical engagement the attacker's average daily advance rate was 0.43 kilometers or only 18% of what it was against the historical hasty defense. The average percent per day casualties for the defender has fallen slightly from the rate incurred in the hasty defense posture (from 0.64% to 0.60%), while those of the attacker have increased significantly (from 0.73% against the hasty defense to 1.73% against the hypothetical fortified defense or an increase by a factor of 2.34). Percent per day tank losses have increased -- the attacker's armor losses from

Table 3-10. The effects of fortifications:
Aprilia, 25-26 January 1944

A. Historical Hasty Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
25-26 Jan	2	A	19,350	248	0.53	248	123	7	2.85	7	4.8	2.4	4.8	0.27	1.19
		D	6,750	98	0.73	98	46	4	4.35	4				0.30	1.81
Average	1	A	19,288	124	0.64		121	3.5	2.89		2.4			0.27	1.20
		D	6,726	49	0.73		45	2.0	4.44					0.30	1.85

B. QJM Replication with Hasty Defense

25-26 Jan	2	A	19,350	238	0.61	238	123	9	3.66	9	5.62	2.81	5.62	0.22	1.30
		D	6,750	102	0.76	102	46	3	3.26	3				0.27	1.16
Average		A	19,291	119	0.62		121	4.5	3.72		2.81			0.22	1.32
		D	6,725	51	0.76		45	1.5	3.33					0.27	1.19

C. Hypothetical Fortified Defense

25-26 Jan	2	A	19,350	230	0.59	230	123	11	4.47	11	0.86	0.43	0.86	1.37	10.40
		D	6,750	231	1.72	231	46	7	7.61	7				4.00	17.70
Average	1	A	19,293	115	0.60		120	5.5	4.58		0.43			1.40	10.65
		D	6,692	116	1.73		44	3.5	7.95					4.02	18.49

2.89% to 4.58% (an increase by a factor of 1.79). The average percent casualties per kilometer advanced or retreated was 1.40% for the attacker and 4.02% for the defender, increases by factors of 5.19 and 13.40 respectively over the same rates for the hasty defense. The average percent tank losses per kilometer advanced or retreated was 10.65% for the attacker and 18.49% for the defender, increases by factors of 8.88 and 9.99 respectively over the same rates for the hasty defense.

These results show that, had the Germans been in a prepared-fortified posture at Aprilia, the British advance would not have gained the key Factory complex, its immediate objective, in two days of combat. Since the German force defending in the Anzio-Albano road sector more than doubled in strength on 27 January and counterattacked at the Factory, the consequences of not seizing the Factory in the operations of 25-26 January might have been grave.

Terracina, 22-23 May 1944

German plans for the defense of the Italian peninsula south of Rome were predicated on the defense of successive lines of strategic field fortifications constructed roughly east-west across the peninsula and solidly based on the rugged, difficult terrain of the Apennine Mountains. Following the successful Allied landings at Salerno and Taranto in September 1943, the Germans withdrew their out-numbered Tenth Army to the first of these fortified lines and prepared to arrest the Allied attack on Central Italy and Rome. The Allies, following, then fought the Volturno Campaign (12 October-8 December 1943) and breached two of the three major defense lines in the German Winter Line Zone. The third and most powerful line, the Gustav Line, checked further Allied advances until May 1944, when it was broken by the Allied DIADEM Offensive.

The Germans, realistically, understood that the Gustav Line might eventually fall to a massive Allied offensive. So, in the months preceding DIADEM, they constructed other fortified lines behind the Gustav Line. The first of these, proceeding northward, was the Hitler Line, which blocked the Liri Valley some miles behind the Gustav Line-Cassino front; the second was the "C" Line, based on the Alban Hills below Rome; and the third was the Campagna Line, which covered suburban Rome near the coast. None of these lines was completed, and each had substantial weaknesses which were revealed in the Rome Campaign (11 May-4 June 1944).

The engagement at Terracina occurred on the right (seaward) flank of the incomplete Hitler Line. However, German preparations for the defense of Terracina had been limited to the construction of permanent works to defend against a seaborne attack. On the landward side of the town, where the terrain was dominated by the forbidding massif of the Ausoni Mountains, the Germans had almost completely neglected to prepare fortifications, judging (incorrectly) that the Allies would not attempt an attack across rugged terrain where their superiority in armor and artillery would be largely negated. In any event, the Germans reasoned that if the attempt was made it would be an easy matter to oppose it from the dominant heights.

German assumptions about the strength of the Terracina position were proved wrong when, on 22 May 1944, the US 85th Infantry Division pursued the beaten remnants of the 115th Panzer Grenadier and 94th Infantry Divisions to the vicinity of the town and the flanking mountains. The commitment of the fresh 29th Panzer Grenadier Division (arriving from Army Group C reserve on the 22d) temporarily halted the American advance but could not significantly affect the overall situation in the Terracina area.

When the Americans renewed their attack in the afternoon of the 22d the Germans were driven from the mountains into Terracina by a series of concentric attacks, and two American infantry regiments penetrated the Ausoni massif toward Sonnino, creating the possibility of a wide envelopment of German forces remaining in the vicinity of Terracina. These developments forced the Germans to abandon the defense of the sector at midnight on 23 May and retreat north and east toward the "C" Line and Rome.

Table 3-11(A) shows the force strengths and engagement outcomes in the historical battle at Terracina. The attacker's advance rate, averaged over two days, was 2.68 kilometers per day -- a very respectable rate considering the degradation of velocity imposed by the rugged terrain. The average daily personnel casualties of the defender were 127 men or 1.93%. The average percent casualties per kilometer advanced or retreated were 0.20% for the attacker and 0.72% for the defender. The average daily tank losses of the attacker were five tanks or 3.23%; those of the defender were two tanks or 8.00%. The average percent tank loss per kilometer advanced or retreated was 1.21% for the attacker and 2.99% for the defender.

Table 3-11. The effects of fortifications: Terracina, 22-23 May 1944

A. Historical Hasty Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
22-23 May	2	A	18,030	192	0.53	192	157	10	3.18	10	5.36	2.68	5.36	0.20	1.19
		D	6,653	254	1.91	254	26	4	7.69	4				0.71	2.87
Average	1	A	17,982	96	0.53		155	5	3.23		2.68			0.20	1.21
		D	6,590	127	1.93		25	2	8.00					0.72	2.99

B. QJM Replication with Hasty Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
22-23 May	2	A	18,980	200	0.55	200	157	21	6.69	21	6.4	3.2	6.4	0.17	2.09
		D	6,653	151	1.14	151	26	3	5.77	3				0.36	1.80
Average	1	A	17,980	100	0.56		152	10.5	6.91		3.2			0.18	2.16
		D	6,615	76	1.15		25	1.5	6.00					0.36	1.88

C. Hypothetical Fortified Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
22-23 May	1	A	18,030	174	0.48	174	157	11	3.50	11	1.46	0.73	1.46	0.66	4.79
		D	6,653	148	1.11	148	26	3	5.77	3				1.52	7.90
Average	1	A	17,987	87	0.48		154	5.50	3.57		0.73			0.66	4.89
		D	6,616	74	1.12		25	1.50	6.00					1.53	8.22

These figures illustrate the extent to which the Germans had miscalculated the defensive potential of the terrain (unimproved by field fortifications) in the Terracina sector. It is interesting to note, in this connection, that a similar mistake was made by the Germans in the Monte Majo sector of the Gustav Line opposite the French Expeditionary Corps. The French breakthrough to Monte Majo over "impossible" terrain on 13 May 1944 unhinged the Gustav Line defenses in the XIV Panzer Corps zone opposite the Fifth Army and contributed significantly to the collapse of the Gustav Line. In both instances the defender's chance of success was diminished decisively because a skillful, numerically stronger attacker massed overwhelming combat superiority at a point the defender neglected because of the apparent unsuitability of the terrain for offensive warfare. It is perhaps superfluous to point out here that history affords numerous examples of similar miscalculations, not least being the German Ardennes offensives of 1940 and 1944.

Table 3-11(B) shows the QJM replication of the historical engagement at Terracina. The attacker's average daily advance rate, historically 2.68 kilometers, has been computed as 3.20 kilometers, a 19% increase over the historic rate. The computer has replicated the average percent per day personnel casualties of the attacker very closely (0.53% historically; 0.56% in the replication) but the correlation is less close for the defender (1.93% historically; 1.15% in the replication). However, this apparent anomaly (which is not a serious discrepancy in casualty relationship) is explainable by the fact that the historic estimate of German casualties includes substantial numbers of prisoners taken incidental to the engagement, but not necessarily related directly to it (the 85th Division recorded taking 141 prisoners on 22 May alone). Since the computer will generate only averages for casualties incurred "in the heat of battle," and since many of the prisoners taken by the 85th Divison were probably demoralized troops captured during the German retreat both before and after the engagement but are not (given the data) separable from prisoners taken during the engagement, the discrepancy is clearly negligible. As far as tank losses are concerned, the replication has overestimated the average percent per day loss of the attacker by a factor of 0.47, that is, generated a loss rate 114% greater than the historic rate. This is explainable by the fact that the Terracina operation was largely an infantry battle and

the armor accompanying the attacking infantry was not fully committed because of constraints imposed by the terrain. (This is a phenomenon noted in other tank-supported infantry battles.) The defender's average percent per day tank losses were generated at 6.00% or 75% of the historical rate, 8.00%.

Table 3-11(C) shows the QJM-generated outcomes of a hypothetical engagement at Terracina assuming the Germans had fortified the Ausoni massif. Note that largely because of his preponderant force superiority the attacker is still able to make a respectable advance despite the degradation of velocity imposed by the combination of terrain and the defender's fortified posture. However, the attacker's average daily advance has been reduced to 0.73 kilometers -- or 27% of what it was against the historical hasty defense. At that rate, a complete breakthrough of a hypothetical fortified zone in the Terracina sector would have required from four to five days of offensive effort on the part of the 85th Division. Such a delay, assuming similar delays in the sectors of other Allied divisions along the line to the right of the 85th Division (where also the Hitler Line was in large part little more than a line on German operational maps), would have delayed in turn the disastrous full scale withdrawal of the German Tenth Army across the length of the southern front. It would most certainly have diminished the results of the combined effects of DIADEM and BUFFALO -- the Anzio breakout operation.

Note also that in this hypothetical example the daily average casualties of both the attacker and the defender have fallen, those of the attacker from 96 men or 0.53% per day to 87 men or 0.48% per day, and those of the defender from 127 men or 1.93% per day to 74 men or 1.12% per day. The saving to the attacker is minimal (nine men or 0.05% per day), but the saving to the defender is significant (53 men or 0.81% per day). The average daily casualties per kilometer advanced or retreated increase for the defender from 0.20% in the hasty defense to 0.66% in the fortified defense, that is, by a factor of 3.30; for the attacker the increase is from 0.72% against the hasty defense to 1.53% against the fortified defense, an increase by a factor of 2.13. Numerical tank losses for both sides in both defensive postures remain roughly the same, but the average percent loss of tanks per kilometers advanced or retreated increases for the attacker from 1.21% against the hasty defense to 4.89% against the fortified defense -- an increase by a factor of 4.04 -- and for the defender the same figures are 2.99% and 8.22% -- an increase by a factor of 2.75.

Valmontone, 1-2 June 1944

The commitment of the Hermann Goering Panzer Parachute Division southeast of Rome on 27 May 1944 represented a desperate attempt by Field Marshal Albert Kesselring, German commander in chief in Italy, to stem the tide of the Allied advance from the Anzio beachhead along the Cisterna-Valmonte axis -- an offensive that threatened to thrust a wedge between the German Tenth and Fourteenth Armies and to cut Route 6, the major line of retreat of the right wing of the Tenth Army from the Cassino area. The German problem was mitigated to a certain extent when, on 26 May, General Mark Clark, the US Fifth Army Commander, abruptly changed the nature and direction of the main Allied advance, shifting the weight of the VI Corps's drive to the northwest, away from the Valmontone Gap and Route 6. But the advance on Valmontone was continued by the US 3d Infantry Division, reinforced by Task Force Howze of the 1st Armored Division and the 1st Special Service Force (1st SSF). Thus, the Hermann Goering Division, which was relatively fresh, and fragments of other commands shattered and disorganized by the Allied offensive, had still to contend with an adversary who possessed a preponderant numerical and materiel advantage.

The first clashes between the Hermann Goering Division's advance elements and the 3d Division force occurred on 27 May on open, rolling terrain in the vicinity of Artena, just four kilometers south of Valmontone. The American advance was caught off balance and driven back in one sector when the Germans launched two sharp counterattacks. These attacks were repelled, and the 3d Division resumed its attack behind the tanks of Task Force Howze. Tentative efforts by Task Force Howze to reach Route 6 were turned back by heavy fire from German self-propelled guns.

The same pattern of attack and counterattack repeated itself during 28-31 May, but by the evening of the 31st the 3d Division force had gained a position along the railroad embankment two kilometers south of Valmontone and was concentrating for the final thrust to cut Route 6.

The 3d Division was now quite close to its objective, and the Germans found themselves unable any longer to engage in the mobile defense they had employed since the 27th. Their dilemma was complicated by the fact that "C" Line fortifications, which covered the southern approaches to

Rome from the Tyrrhenian Sea to Velletri at the base of Monte Artemisio, had not been extended eastward to cover the Valmontone Gap. Some light field fortifications, including dugouts, communications trenches, and scattered weapons emplacements, had been constructed along Route 6, but no systematic attempt had been made to fortify the sector east of Velletri, and the German defenses, besides being incomplete, had not been echeloned in depth.

The 3d Division launched its offensive at 0500 on 1 June and accomplished its original mission of cutting Route 6 by 2100 hours. Valmontone was occupied on the morning of 2 June after stiff German resistance to the south of the town was mopped up. From Valmontone elements of the 3d Division force advanced north to Palestrina and north and west up Route 6 toward Labico and Rome. The Hermann Goering Division, having suffered serious losses, withdrew to the north, crossing the Tiber bridges above Rome. On 4 June the 3d Division's Reconnaissance Troop and Battle Patrol entered the city of Rome.

Qualitative and quantitative analysis of the Valmontone engagement shows the extent to which the defensive posture of the Hermann Goering Division would have been enhanced had the "C" Line fortifications been extended to cover the Valmontone Gap.

Table 3-12(A) shows the historical outcomes of the engagement at Valmontone. The average daily personnel casualties of the attacker were 355 men or 1.35%; those of the defender were 284 men or 2.85%. The average daily tank losses of the attacker were 3.50 tanks or 2.50%; those of the defender were four tanks or 13.33%. The average distance the attacker advanced per day was 2.60 kilometers. The average percent casualties per kilometer was 0.52% for the attacker and 1.10% for the defender. The average percent loss of tanks per kilometer was 0.96% for the attacker and 5.13% for the defender.

Table 3-12(B) shows the QJM simulation of the historical engagement at Valmontone. The average daily personnel casualties of the attacker are 277 men or 1.05% (77% of the historical figure); those of the defender are 204 men or 2.04% (72% of the historical figure). The average daily tank losses of the attacker are 13 tanks or 9.56% (382% of the historical figure); those of the defender are four tanks or 13.33% (which duplicates the historical figure). These figures replicate average daily personnel

Table 3-12. The effects of fortifications:
Valmontone, 1-2 June 1944

A. Historical Prepared Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	%Cas /km	%Tanks /km
1 Jun	1	A	26,607	471	1.77	471	143	6	4.20	6	2.50	2.50	2.50	0.71	1.68
		D	10,111	284	2.81	284	32	4	12.50	4				1.12	5.00
2 Jun	1	A	26,136	239	0.91	710	137	1	0.73	7	2.70	2.70	5.20	0.34	0.27
		D	9,827	284	2.89	568	28	4	14.29	8				1.07	5.29
Average	1.0	A	26,372	355	1.35		140	3.50	2.50		2.60			0.52	0.96
		D	9,969	284	2.85		30	4.00	13.33					1.10	5.13

B. QJM Replication with Prepared Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	%Cas /km	%Tanks /km
1-2 Jun	2	A	26,607	554	1.04	554	143	26	9.37	26	5.40	2.70	5.40	0.39	3.47
		D	10,111	408	2.01	408	32	8	11.88	8				0.75	4.40
Average	1.0	A	26,468	277	1.05		136	13	9.56		2.70			0.39	3.54
		D	10,009	204	2.04		30	4	13.33					0.76	4.94

C. Hypothetical Fortified Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	%Cas /km	%Tanks /km
1-2 Jun	2	A	26,607	970	1.82	970	143	63	21.87	63	1.66	0.83	1.66	2.19	26.35
		D	10,111	238	1.18	238	32	6	8.66	6				1.42	10.43
Average	1.0	A	26,364	485	1.84		127	31.50	24.80		0.83			2.22	37.95
		D	10,051	119	1.18		30	3.00	10.00					1.42	12.05

casualties and tank losses in the historical battle quite well. The replication figures for the attacker's tank losses may be questioned but are explicable in light of the very heavy materiel losses of the Hermann Goering Division to Allied fighter-bombers in its forced march from Pisa to Valmontone. When the division was committed in the Artena-Valmontone sector on 27 May, it was very weak in materiel and especially deficient in antitank means. Thus, the historical tank losses of the attacking US force were considerably less than average for engagements of this intensity.

The replication average daily rate of advance is 2.70 kilometers, very close to the historical rate, 2.60 kilometers. The average percent personnel casualties per kilometer is 0.39% for the attacker and 0.76% for the defender. The average percent tank losses per kilometer is 3.54% for the attacker and 4.94% for the defender.

Historically, the 3d Division's attack to cut Route 6 from the railroad embankment about equidistant from Valmontone and Artena covered approximately 2.5 kilometers and took 16 hours. The attack was made over open, rolling terrain almost devoid of cover. The only obstacles to the attacker's armor were a second railroad embankment running parallel to Route 6 and a few hasty minefields laid by the defender. The railroad embankment provided cover for German tanks and self-propelled guns, which destroyed or disabled six American tanks on 1 June. Once this obstacle was passed, however, the sparse and shallow positions along Route 6 were easily penetrated, and the American armor was freed to attack into the depth of the German position and exploit the breakthrough. On 2 June the defenses were rolled up to the northwest, and the penetration became a pursuit.

A comparison of the rates of advance, casualties, and tank losses in this engagement with those of the assault against the "C" Line fortifications west of the Alban Hills in the sector of the US 45th Infantry Division (see Table 3-13) shows graphically what might have been the case had the Hermann Goering Division had the benefits of a fortified position.

The most apparent difference between the two engagements as reflected in the engagement outcomes shown in the table is in the rates of advance. The average daily rate of advance against the prepared defense at Valmontone

Table 3-13. Comparison of engagement outcomes: two engagements in the Rome Campaign

A. Valmontone: U. S. Attack v. German Prepared Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	%Cas /km	%Tanks /km
1 Jun	1	A	26,607	471	1.77	471	143	6	4.20	6	2.50	2.50	2.50	0.71	1.68
		D	10,111	284	2.81	284	32	4	12.50	4				1.12	5.00
2 Jun	1	A	26,136	239	0.91	710	137	1	0.73	7	2.70	2.70	5.20	0.34	0.27
		D	9,827	284	2.89	568	28	4	14.29	8				1.07	5.29
Average	1.0	A	26,372	355	1.35		140	3.50	2.50		2.60			0.52	0.96
		D	9,969	284	2.85		30	4.00	13.33					1.10	5.13

B. Via Anziate: U.S. Attack v. German Fortified Defense

1-2 Jun	2	A	23,604	480	1.02	480	220	8	1.82	8	0.80	0.40	0.80	2.55	4.55
		D	19,255	884	2.30	884	35	12	17.14	12				5.75	42.85
Average	1	A	23,364	240	1.03		216	4	1.85		0.40			2.58	4.63
		D	18,813	442	2.35		29	6	20.69					5.86	51.73

was 2.6 kilometers, six-and-a-half times greater than the average daily rate of advance against the fortified defense at Via Anziate, 0.4 kilometers. Percent per day personnel losses were lower at Via Anziate than at Valmontone, but percent personnel casualties per kilometer advanced shows a dramatic increase at Via Anziate as compared to Valmontone. The average kilometer of projected advance at Via Anziate would have cost the American force 2.58% of its personnel strength; the defender would have lost 5.86% of his personnel strength contesting that advance. At Valmontone the same figures respectively were 0.52% and 1.10%. A comparison of tank losses in the two engagements is less instructive, since the US armor at Via Anziate did not spearhead the attack as it did at Valmontone but instead kept back in assembly areas. (The 1st Armored Division had made an attack in the same sector on 29-31 May and had been repulsed with a loss of 65 tanks; the 45th Division passed through the 1st Armored's line to advance to the attack on 1 June.)

A more precise prediction of engagement outcomes at Valmontone, assuming a hypothetical fortified defense, is provided by QJM-generated data. These outcomes, shown in Table 3-12(C), indicate that, had the "C" Line been extended to cover the Valmontone Gap, the 3d Division's rate of advance would have been slowed from an average of 2.6 kilometers per day to an average of 0.83 kilometers per day. Average percent per day casualties in the fortified mode would have increased for the attacker (from 1.35% per day to 1.84% per day) but decreased dramatically for the defender (from 2.85% per day to 1.18% per day) compared to the prepared mode. The cost to the attacker of a kilometer advanced against a hypothetical fortified defense compared to the historical prepared defense increases from 0.52% personnel per kilometer to 2.22% personnel per kilometer, an increase by a factor of 4.27. The same figure for armor losses rises from 0.96% tanks per kilometer to 37.95% per kilometer, an increase by a factor of 39.53. The defender's casualties and losses in these categories, on the other hand, show relatively smaller increases.

Such outcomes show that, hypothetically, a 3d Division attack against a fortified zone at Valmontone would have failed to penetrate the German defenses significantly and cut Route 6. The attack would certainly have failed to gain the railroad embankment on 2 June. Also, German fire from the railroad embankment and the high ground behind Valmontone in the

vicinity of Cave and Palestrina would have taken a heavy toll of American troops and armor.

Whether or not the Germans would have been able to stop a determined American advance subsequent to 2 June remains conjectural. The Hermann Goering Division was the last major German reserve in Italy; the Allies, on the other hand, were adding units from the Cassino front daily to the troops already on hand in the Anzio-Valmontone sector. Given the same force ratios at Valmontone as existed on 1-2 June, an American penetration to cut Route 6 would have been unlikely. However, a powerful reinforcement of US II Corps and FEC (French Expeditionary Corps) troops from the Minturno and Cassino fronts would have changed the combat power ratios at Valmontone radically and permitted a breakthrough, probably on 3 June.

The example of the defense of the "C" Line west of Velletri provides confirmation of this hypothetical series of events. The Germans at Via Anziate and elsewhere along the "C" Line continued to resist strongly and deny significant advances to the Allies until midnight of 3 June, when they abruptly abandoned the defense and broke contact. This withdrawal was caused primarily by the breakthrough at Valmontone, which placed American forces squarely in the rear of the Fourteenth Army's left wing and threatened the escape route to Rome of the troops manning the "C" Line.

Sauer River Defense, 16-17 December 1944

In mid-December 1944 the US 4th Infantry Division held an extended 50-kilometer front that anchored the right (extreme southern) flank of the US First Army in the Sauer River sector of Luxembourg. When the Germans launched their Ardennes offensive on the 16th the 4th Division was attacked by the 212th Volks Grenadier Division. This attack was facilitated by substantial surprise and failure of the US force to provide adequately for the security of its position and to prepare adequate obstacles and barriers in the weeks before 16 December.

In this engagement, which lasted two days, until the intervention of powerful armored units from the US Third Army ended it, the main thrust of the German attack fell on the 4th Division's 12th Infantry Regiment, which had a slightly improved hasty defense posture.

Table 3-14(A) shows the historical outcomes in this engagement. The German advance rate, enhanced by substantial surprise, averaged 3.17 kilometers per day, despite the delay effects imposed by rugged, defensible

Table 3-14. The effects of fortifications: Sauer River Defense, 16-17 December 1944

A. Historical Hasty Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
16 Dec	1	A	10,000	134	1.34	134	4	1	25.00	1	2.64	2.64	2.64	0.51	9.47
		D	8,634	67	0.78	67	59	2	3.39	2				0.30	1.28
17 Dec	1	A	9,866	134	1.35	268	3	1	33.33	2	3.70	3.70	6.34	0.37	9.01
		D	8,567	67	0.78	134	58	1	1.72	3				0.21	0.46
Average	1	A	9,933	134	1.35		3.5	1	28.57		3.17			0.43	9.01
		D	8,567	67	0.78		58.5	1.5	2.56					0.25	0.81

B. QJM Replication with Hasty Defense

16-17 Dec	2	A	10,000	223	1.11	223	4	2	25.00	2	5.73*	2.87	5.73	0.39	8.71
		D	8,634	118	0.68	118	59	5	4.24	5				0.24	1.48
Average	1	A	9,944	111	1.12		3.5	1	29.00		2.87			0.39	10.10
		D	8,603	59	0.63		57.25	2.5	4.37					0.22	1.52

*Advance of 2.66 km on 16 December; 3.07 km on 17 December.

C. Hypothetical Fortified Defense

16-17 Dec	2	A	10,000	385	1.92	385	4	3	37.50	3	1.44*	0.72	1.44	2.67	52.08
		D	8,634	84	0.49	84	59	3	2.54	3				0.68	3.53
Average		A	9,904	192	1.94		3.5	1.5	42.86		0.72			2.69	59.53
		D	8,613	42	0.49		58.0	1.5	2.59					0.68	3.60

* Advance of 0.67 km on 16 December; 0.77 km on 17 December.

terrain (extensive forests, streams, and ravines). This is a striking accomplishment, illustrating the extent to which the German division satisfactorily completed its mission, which was to attack to cover the left flank of the main offensive effort and to hold substantial American forces in the area. The average daily personnel casualties of the attacker were 134 men or 1.35% per day; the average daily personnel casualties of the defender were 67 men or 0.78% per day. The average percent casualties per kilometer advanced or retreated was 0.43% for the attacker and 0.25% for the defender. It should be noted that the Germans achieved this success while enjoying only a very slight superiority in manpower (1.16-1.00) and firepower (very slightly more than 1.00-1.00 as measured by proving ground OLI values). The German success, then, may be attributed in large part to the achievement of substantial surprise (which seems to have multiplied the German advance rate by a factor of approximately 1.25 over the two days of the engagement) and by the failure of the defender to prepare his position adequately for defense.

Table 3-14(B) shows the computer-generated engagement outcomes for the QJM replication of the Sauer River defense. The average daily personnel casualties of the attacker are 111 men or 1.12% (83% of the historical figure); those of the defender are 59 men or 0.63% (81% of the historical figure). The average daily tank losses of the defender are 2.50 tanks or 4.37%, which exceeds the historical figure by a factor of 1.71. The attacker's average daily advance rate is 2.87 kilometers, which is 91% of the historical rate. Average percent casualties per kilometer is 0.39% for the attacker and 0.22% for the defender. Average percent tank losses per kilometer is 10.10% for the attacker and 1.52% for the defender. Each of these engagement outcome figures correlates very well with its counterpart in the historical Sauer River engagement.

Table 3-14(C) shows the computer-calculated outcomes of a hypothetical version of this engagement in which the defender's posture is assumed to be fortified defense. Note here that full field fortifications have reduced the attacker's rate of advance from the historical average of 3.17 kilometers per day to an average of 0.72 kilometers per day -- a rate only 23% of the historical advance rate against a hasty defense. Surprise, of course, is assumed in this hypothetical example, and has

enhanced the attacker's advance rate, but its effects, normally very significant, have been substantially degraded by the defender's fortified posture.

Note also that in the hypothetical example the attacker's average daily casualties have risen significantly, while those of the defender have fallen. The average daily casualties of the attacker are 192 men or 1.94%. That is 43% larger than the historical attrition rate against hasty defense. The average daily casualties of the defender, on the other hand, are 42 men or 0.49% in the hypothetical fortified defense posture -- or 63% of what they were in the historical hasty defense. More significant still are the results for percent casualties per kilometer advanced. Against the hypothetical fortified defense, the German loss rate would have been an average 2.69% personnel strength per kilometer advanced, an increase by a factor of 6.26 over the same rate for the historical hasty defense. The defender's average percent casualties per kilometer of attacker's advance, on the other hand, increases from 0.25% in the hasty defense to 0.68% in the fortified defense, that is, an increase by a factor of 2.72.

US tank losses at the Sauer River remain numerically the same in both defensive modes, but the percentage of tanks lost per kilometer of attacker's advance increases from an average of 0.81% in the hasty posture to an average of 3.60% in the fortified posture, an increase by a factor of 4.44. German tank losses are estimated, since no data on them is available. Thus, reliable comparisons are impossible. However, this is not significant since the Germans did not have (and would not have had) the front line assistance of their armor; American artillery interdiction of the Sauer and its approaches thwarted every attempt to bridge the river until the 19th, and the attacker was forced to operate without tanks and heavy weapons on the west side of the river until that date.

Jebel Geneifa, 19-22 October 1973

On 16 October 1973 Israeli forces penetrated the Egyptian bridgehead on the east bank of the Suez Canal near the boundary between the Egyptian Second and Third armies and began crossing the canal to the west bank. As part of this operation Israeli General Adan's division crossed the canal near Deversoir on the northern edge of the Great Bitter Lake in the evening

of 17 October. The division's mission was to wheel south and cut the lines of communication of the Egyptian Third Army, a large portion of which was in defensive posture on the southern flank of the Egyptian bridgehead on the east bank of the canal.

Adan's Division, which numbered 16,200 men and 318 tanks, began to move south on the morning of 19 October. Facing Adan were 35,633 men and 454 tanks of the Egyptian Third Army. In the first phase of the operation (19-21 October) the Israeli troops took the rugged Geneifa hills southwest of the Great Bitter Lake before the Egyptians could establish defensive positions, and overcame serious opposition from the defenders of the town of Fayid, which was located near the Great Bitter Lake.

Then, on 21 October, Adan's Division struck south from the Geneifa hills and advanced to within ten kilometers of the Sarag road, which connected Cairo with Suez City and was the last open link between the Third Army and Cairo. Egyptian counterattacks stopped Israeli attempts to advance to the road itself, but Israeli tank and artillery fire effectively interdicted traffic on the road.

Early on 22 October General Adan learned that there would be a ceasefire at 1800 hours. He then ordered his division to continue to attack eastward to establish positions along the canal between Suez and the Bitter Lakes before the ceasefire would take effect. The attack succeeded despite desperate Egyptian resistance. Other forces attacked south and successfully cut the Sarag road. By the time the ceasefire took effect, Adan's division had successfully isolated Suez and the Egyptian Third Army and had established positions on the west bank of the canal opposite the Israeli-controlled portion of the east bank for resupply and communications purposes.

Table 3-15(A) shows the outcomes of the historical engagement in the Jebel Geneifa sector. The attacker's average daily advance rate was 14.30 kilometers. The Egyptian Third Army had few fortified positions west of the canal and consequently had little time to organize an effective defense to slow the Israeli advance.

The attacker's average daily casualties were 100 men or 0.62%; those of the defender were 550 men or 1.57%. The average daily tank losses of the defender were 10 tanks or 3.25%; those of the defender were 38 tanks or 9.13%. The average percent personnel casualties per kilometer was

Table 3-15. The effects of fortifications:
Jebel Geneifa, 19-22 October 1973

A. Historical Hasty Defense

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
19-22 Oct	3	A	16,200	300	0.62	300	318	30	3.14	30	42.90	14.30	42.90	0.04	0.22
		D	35,633	1,650	1.54	1,650	454	114	8.37	114				0.11	0.59
Average	1.0	A	16,100	100	0.62		308	10	3.25		14.30			0.04	0.23
		D	35,083	550	1.57		416	38	9.13					0.11	0.64

B. QJM Replication with Hasty Defense

19-22 Oct	3	A	16,200	222	0.46	222	318	24	2.52	24	32.82	10.94	32.82	0.04	0.23
		D	35,633	1,470	1.38	1,470	454	101	7.42	101				0.13	0.67
Average	1.0	A	16,126	74	0.46		310.00	8.00	2.58		10.94			0.04	0.24
		D	35,143	490	1.39		420.33	33.67	8.01					0.13	0.73

C. Hypothetical Fortified Defense

19-22 Oct	3.0	A	16,200	455	0.94	455	318	50	5.24	50	1.83	0.61	1.83	1.54	8.59
		D	35,633	3,013	2.82	3,013	454	207	15.20	207				4.62	24.92
Average	1.0	A	16,048	152	0.95		301.33	16.67	5.53		0.61			1.56	9.07
		D	34,629	1,004	2.90		385.00	69.00	17.92					4.75	29.38

0.04% for the attacker and 0.11% for the defender. The average percent tank losses per kilometer was 0.23% for the attacker and 0.64% for the defender.

Table 3-15(B) shows the outcomes of the QJM replication of the engagement at Jebel Geneifa. The attacker's average daily advance is 10.94 kilometers, or 77% of the historical advance rate. The average daily personnel casualties of the attacker are 74 men or 0.46%; those of the defender are 490 men or 1.39%. The figures compare very well with the same figures for the historical engagement, being smaller by factors of 0.74 and 0.89 respectively. The average daily tank losses of the attacker are eight tanks or 2.58%; those of the defender are 33.67 tanks or 8.01%. These figures, likewise, compare well with the same historical figures, being smaller by factors of 0.79 and 0.88 respectively. The average percent casualties per kilometer is 0.04% for the attacker and 0.13% for the defender. The attacker's figure duplicates the historical figure; that of the defender is larger by a factor of 1.18. The average percent tank losses per kilometer is 0.24% for the attacker and 0.73% for the defender. These figures correspond to the same historical figures by factors of 1.04 and 1.14 respectively.

Table 3-15(C) shows the computer-generated outcomes of a hypothetical engagement at Jebel Geneifa, assuming that the Egyptians had a fortified defense opposed to the Israeli advance. As the table shows, such a defense would have slowed the Israeli advance to a daily average of 0.61 kilometers, or just 4% (0.04) of the rate against the historical hasty defense. The attacker's average daily personnel casualties are 152 men or 0.95%; those of the defender are 1,004 men or 2.90%. These figures show an increase by factors of 1.53 and 1.85 respectively over the same figures for the historical hasty defense. The average daily tank losses are 16.67 tanks or 5.53% for the attacker and 69 tanks or 17.92% for the defender. These figures show an increase by factors of 1.70 and 1.96 respectively over the same historical figures. The figures for average percent personnel casualties per kilometer and average percent tank losses per kilometer show very large increases over the same figures for the historical hasty defense. The average percent casualties per kilometer is 1.56% for the attacker and 4.75% for the defender. These figures are larger than the same historical figures by factors of 39.00 and 43.18 respectively. The

average percent tank losses per kilometer is 9.07% for the attacker and 29.38% for the defender. These figures are larger than the same historical figures by factors of 39.43 and 45.91 respectively.

A comparison of Table 3-15(C) with 3-15(A) shows that, had the Egyptians fortified the west bank of the canal to protect the Third Army's rear area, Adan's Division could not have advanced very far south from the Deversoir bridgehead. The main lines of communication and supply of the Third Army would have been undisturbed by the Israeli crossing.

Tel Fars, 8-10 October 1973

At the beginning of the 1973 Arab-Israeli War the Syrian 5th Infantry Division, which had 23,750 men and 253 tanks, was deployed along the ceasefire line (the "Purple Line") between Syria and the Israeli-occupied Golan Heights just south of the town of Rafid in the southern Golan. During the first two days of the war (6-7 October) this division advanced roughly 15 kilometers into the Golan area and isolated the Israeli strong point at Tel Fars. By afternoon of 7 October the Syrians had reached the last high ground east of the Sea of Galilee and the Jordan River. There the divisions encountered strong Israeli opposition, and its advance was brought to a halt. On 8 October the Israeli Peled Division, which numbered 17,833 men and 249 tanks, counterattacked and began to push the Syrian division back. On 9 October the Peled Division relieved Tel Fars and continued its attack toward the "Purple Line," which it reached on 10 October. The terrain in the area of this engagement was slightly rough and undulating. The weather was sunny and hot. Neither side had established air superiority during the period of the engagement.

Table 3-16(A) shows the historical outcomes of the Tel Fars engagement. The Syrians, in a hasty-mobile posture, relinquished ground at an average daily rate of six kilometers. The Syrians fought well but never had time to regroup after being struck by the Peled Division. The attacker's average daily casualties were 75 men or 0.42%; those of the defender were 250 men or 1.06%. The average daily tank losses were 8 tanks or 3.32% for the attacker and 44 tanks or 21.05% for the defender. The average percent casualties per kilometer were 0.07% for the attacker and 0.18% for the defender. The average percent tank losses per kilometer were 0.55% for the attacker and 3.51% for the defender.

TABLE 3-16. THE EFFECTS OF FORTIFICATIONS: TEL FARS, 8-10 OCTOBER 1973

A. HISTORICAL HASTY DEFENSE

Dates		Days	Personnel Strength	Personnel Cas	Personnel %/Day	Tanks Strength	Tanks Losses	Tanks %/Day	Distance Km	Distance /Day	% Cas /Km	% Tanks /Km
8-10 Oct	A	2.0	17,833	150	0.42	249	16	3.21	12.00	6.00	0.07	0.54
	D		23,750	500	1.05	253	88	17.39			0.18	2.90
AVERAGE	A	1.0	17,758	75	0.42	241	8	3.32		6.00	0.07	0.55
	D		23,500	250	1.06	209	44	21.05			0.18	3.51

B. QJM REPLICATION WITH HASTY DEFENSE

8-10 Oct	A	2.0	17,833	372	1.04	249	33	6.63	9.40	4.70	0.22	1.41
	D		23,750	1,338	2.82	253	84	16.60			0.60	3.53
AVERAGE	A	1.0	17,647	186	1.05	233	16	6.87		4.70	0.22	1.46
	D		23,081	669	2.90	211	42	19.91			0.62	4.24

C. HYPOTHETICAL FORTIFIED DEFENSE

8-10 Oct	A	2.0	17,833	452	1.27	249	41	8.23	1.46	0.73	1.74	11.28
	D		23,750	1,004	2.11	253	63	12.45			2.90	17.06
AVERAGE	A	1.0	17,607	226	1.28	229	20	8.73		0.73	1.75	11.96
	D		23,248	502	2.16	222	31	13.96			2.96	19.12

Table 3-16(B) shows the outcomes of the QJM replication of the engagement at Tel Fars. The attacker's average daily advance rate is 4.70 kilometers, or 78% (0.78) of the historical rate. The average daily personnel casualties of the attacker are 186 men or 1.05%; those of the defender are 669 men or 2.90%. These figures compare with the same historical figures by factors of 0.40 and 0.37 respectively. The average daily tank losses are 16 tanks or 6.87% for the attacker and 42 tanks or 19.91% for the defender. These figures compare with the same historical figures by factors of 0.48 and 1.06 respectively. The average percent casualties per kilometer is 0.22% for the attacker and 0.62% for the defender. The figure for the attacker is over three times the historical figure, while the figure for the defender is high by a factor of 3.44. The average percent tank losses per kilometer are 1.46% for the attacker and 4.24% for the defender. These figures compare with the same historical figures by factors of 2.65 and 0.83 respectively.

Table 3-16(C) shows the QJM-calculated outcomes of a hypothetical engagement at Tel Fars assuming the Syrians had a fortified defense. The attacker's average daily advance rate is 0.73 kilometers, a decrease by a factor of 0.12 from the historical rate. The attacker's average daily personnel casualties are 226 men or 1.28%; those of the defender are 502 men or 2.16%. These figures show that the attacker's casualties would have increased by a factor of 3.05 and those of the defender would have increased by a factor of 2.04 compared to the historical hasty defense. The average daily tank losses are 20 tanks or 8.73% for the attacker and 31 tanks or 13.96% for the defender. These figures compare by factors of 2.63 and 0.66 respectively, to the same historical figures. The percent casualties per kilometer is 1.75% for the attacker and 2.96% for the defender. These figures show increases over the same historical figures by factors of 25.00 and 16.44 respectively. The average percent tank losses per kilometer is 11.96% for the attacker and 19.12% for the defender. These figures show increases over the same historical figures by factors of 21.75 and 5.45 respectively.

A comparison of the outcomes in the hypothetical fortified case with the historical outcomes shows that, had the Syrians somehow managed to fortify their gains up to 8 October, they would have retained most of the southern Golan after a three-day battle in the period 8-10 October.

Historically, of course, they retained almost none of the Golan on 11 October. Another factor, and this is vitally important to a nation with limited manpower like Israel, the high percentage of casualties incurred per kilometer advanced in the hypothetical engagement shows that the Israelis could not have afforded to prosecute such an attack against a fortified position for very long.

CHAPTER IV

THE HYPOTHETICAL EXAMPLE; FULDA GAP, c. 1980

FULDA GAP, c. 1980

In order to determine the probable effects of fortifications on future combat operations the QJM was employed as a combat simulation to assess likely battle outcomes in four variants of a hypothetical corps-level engagement in West Germany in the 1980s. The variants of this engagement selected for this analysis were as follows:

1. Warsaw Pact main effort surprise attack v. NATO hasty defense, conventional.

2. Warsaw Pact main effort surprise attack v. NATO fortified defense, conventional.

3. Warsaw Pact main effort surprise attack v. NATO hasty defense, nuclear exchange (first use by WP).

4. Warsaw Pact main effort surprise attack v. NATO fortified defense, nuclear exchange (first use by WP).

To make valid predictive comparisons between conventional and tactical nuclear war situations, it is necessary to employ compatible models of conventional and tactical nuclear combat. HERO had previously confronted this requirement in its study for DCSOPS and DNA, Analysis of Implications of Surprise in Scenarios of Conventional and Tactical Nuclear Combat in Europe.* As a result, in that study HERO developed a Tactical Nuclear Submodel for the QJM which is completely compatible with, and capable of being used in conjunction with, the standard (conventional warfare) version of the QJM. This QJM/TNSM was employed in this study to simulate the battlefield effects of the use of tactical nuclear weapons in scenarios 3 and 4 (above) in which tactical nuclear exchanges are posited. A description and discussion of the QJM/TNSM is contained in Appendix B.

As a background to this analysis, a scenario was prepared of a hypothetical surprise attack by a Soviet combined arms army on the US V Corps Zone in the Fulda Gap area in the early 1980s.

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*Historical Evaluation and Research Organization, Analysis of Implications of Surprise in Scenarios of Conventional and Tactical Nuclear Combat in Europe (Dunn Loring, Virginia, 1978).

The Soviet attack was assumed to have been launched in early June at 0400 hours (first light) in good weather conditions. The terrain in the area of operations is generally rolling, with mixed vegetation and an excellent road net. The only constraint on movement is imposed by the burgeoning urbanization of the zone, with its complex pattern of cities, towns, villages, and strip areas.* These built-up areas do not yet dominate the terrain to the extent they do in the Ruhr, for example, but they must be taken into consideration as a factor affecting engagement outcomes. Therefore, the simulation terrain factors selected for these cases represents a blend of rolling, mixed and urban terrain.

To achieve consistency among the four cases the Soviet and US maneuver forces and their order of arrival and commitment are identical for each scenario. The air support effort of each side was postulated to be equal.

The Soviet combined arms army, assumed to consist of elements of the Soviet First Guards Tank Army and Eighth Guards Army, had six divisions, four tank divisions, and two motorized rifle divisions. It attacked in two echelons. There were two tank divisions and one motorized rifle division in the first echelon and two tank divisions and one motorized rifle division in the second echelon. Strength, organization, and materiel assets of these elements are current, and attachments of artillery, engineer and motor transport units were made according to assumptions of current Soviet practice.

The US V Corps, defending, consisted of two divisions: one armored and one mechanized infantry division, plus an armored cavalry regiment and corps troops. No reinforcements from other NATO countries took part in the engagement, and US forces from other US corps and CONUS did not participate. US forces were committed to combat as task force (battalion-sized) slices to simplify calculations and manipulation of combat and combat service support. As with the Soviet force, strength, organization, and materiel assets of US elements are current. The order of arrival and commitment of US forces was postulated on the time needed to move combat elements from home stations in the vicinity of Frankfurt and east and west of the Rhine River (some from as far as Baumholder, 200 kilometers distant from the main battle area) given 12 hours notice of the impending Soviet attack. The arrival of these units was considered hampered to a certain

* "strip areas" - small towns next to each other along a road with little or no distinction between towns.

extent by distances from home stations and congestion at traffic choke points, particularly along the Rhine River. Moreover, the disruption of US forces in terms of effects on mobility and vulnerability was assumed to last for the length of each case, declining by one-third for each full combat day.

Order of Battle

Listed below are all significant units committed by both sides, listed for the period in which they were first committed.

a. US Units

D-Day (H-Hr)
- 3 Squadrons Armored Cavalry Regiment
- 1 Squadron Armored Division
- 3 Tank Task Forces Armored Division
- 1 Squadron Mechanized Division
- 1 Tank Task Force Mechanized Division

D+1 (H+24)
- 3 Tank Task Forces Armored Division
- 2 Tank Task Forces Mechanized Division
- 5 Mechanized Task Forces Armored Division
- 3 Mechanized Task Forces Mechanized Division

(H+36)
- 2 Tank Task Forces Mechanized Division
- 3 Mechanized Task Forces Mechanized Division

b. Soviet Units

D-Day (H-Hr)
- 2 Tank Divisions, each plus 1 battalion 122mm howitzer, 2 battalions 130mm guns, 2 battalions 152mm gun/howitzer, 1 battalion 152mm SP howitzer, 1 SCUD brigade, 1 motor transport regiment, 2 army engineer battalions, attack helicopter regiment
- 1 Motorized Rifle Division plus 1 battalion 122mm howitzer, 1 battalion 130mm guns, 2 battalions 152mm gun/howitzer

(H+36)
- 2 Tank Divisions
- 1 Motorized Rifle Division plus independent tank regiment, 1 battalion 130mm guns, 2 battalions 152mm gun/howitzer, 1 motor transport battalion, 2 Army engineer battalions

Combat in the Covering Force Area

In each scenario, combat in the Main Battle Area (MBA) was preceded by combat in the Covering Force Area (CFA), where the US corps covering force conducted a delaying action until reaching the MBA, along the general line Bad Hersfeld-Hunfeld-Gersfeld-Bad Neustadt, where either mobile-hasty or fortified posture (depending on the scenario) was to be adopted. The engagement outcomes of the combat in the CFA have been incorporated into the averaged engagement outcomes for all four cases, since combat in the CFA is assumed to have occurred in each case, regardless of the final posture adopted by the defending force.

When the Soviet attack began, most elements of the armored division had reached their battle positions. But, because of the distances to be travelled, battalions of the mechanized division brigades from the west bank of the Rhine River were still on the road at H-Hour. Only the armored cavalry squadron, and one tank task force of the mechanized division, were able to reach preselected border positions before the Soviet attack struck. Three tank task forces and the armored cavalry squadron of the armored division were able to move to the border area to engage the enemy initially. The corps armored cavalry regiment deployed its three squadrons on line across the corps front.

The first lines of Table 4-1 (and Table 4-2) show the outcomes of the one-sided combat in the CFA. The Soviet first echelon force, aided by substantial surprise, advanced 16.67 kilometers in 24 hours against negligible resistance from the US covering force. Personnel casualties were 184 men or 0.39% for the attacker and 268 men or 2.34% for the defender. Of their 973 tanks and armored combat vehicles, the Soviets lost 37 or 3.80%; the US force, which entered combat with 469 tanks and armored combat vehicles, lost 74 or 15.78%.

Combat in the Main Battle Area, General

The attack through the CFA brought the Soviet first echelon force abreast of the US corps's defenses in the area selected as the MBA. There had not as yet been compelling reasons for the Soviet commander to commit his powerful second echleon force, but US resistance, whatever posture was adopted, stiffened with the commitment of a substantial reinforcement.

Table 4-1. The effects of fortifications:
Fulda Gap, c. 1980

Conventional Soviet Main Effort v. U. S. Hasty Defense*

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
D-Day	1	A	46,784	184	0.39	184	973	37	3.80	37	16.67	16.67	16.67	0.02	0.23
		D	11,455	268	2.34	268	469	74	15.78	74				0.14	0.95
H+24 to H+36	0.5	A	46,600	130	0.56	314	936	25	5.34	62	4.10	8.19	20.77	0.07	0.65
		D	34,462	286	1.66	554	716	31	8.66	105				0.20	1.06
H+36 to H+60	1.0	A	85,120	245	0.29	559	1,699	47	2.77	109	43.06	43.06	63.83	0.01	0.06
		D	43,103	680	1.58	1,234	810	61	7.53	166				0.04	0.17
Average	1	A	61,983	224	0.36		1,237	44	3.56		25.53			0.01	0.14
		D	28,497	494	1.73		625	66	10.56					0.07	0.41

* Covering force battle, delay posture

Combat in the MBA began on D+1 (H+24). For purposes of determining whether or not the Soviet force would have achieved a breakthrough of the US corps defensive area, the corps rear boundary was postulated as following generally the line Neukirchen-Lauterbach-Flieden-Bad Bruchenau; penetration of that line was considered indicative of a breakthrough. The depth of the MBA at the most sensitive points -- the high speed axes of advance along the E 70-E 4 autobahns in the north of the corps zone and along Highway 40 in the south -- was 17.5 and 15 kilometers, respectively.

Case 1: Main Effort, Surprise v. Hasty Defense, Conventional

Table 4-1 shows the computer-generated engagement outcomes of combat in the CFA and MBA assuming a Soviet main effort surprise attack versus a US hasty defense in the MBA. The attacker's average daily rate of advance over 60 hours of combat in this scenario was 25.53 kilometers. Average daily personnel casualties were 224 men or 0.36% for the attacker and 494 men or 1.73% for the defender. Average daily tank losses (including ARVS)* were 44 tanks or 3.56% for the attacker and 66 tanks or 10.56% for the defender. Average personnel casualties per kilometer advanced or retreated were 0.01% for the attacker and 0.07% for the defender; average tank casualties per kilometer were 0.14% for the attacker and 0.41% for the defender. (These figures include the statistics for the covering force battle.)

The table shows that the hasty defense and the commitment of US reinforcements (which restored some measure of balance to the combat power ratios -- still, at the start of the period, H+24 , 1.82 in favor of the attacker) slowed the Soviet advance to a pace of 8.19 kilometers per day (4.10 kilometers during the period H+24-H+36). The commitment of the Soviet second echelon, however, at H+36 sealed the fate of the US defense. The combat power ratio soared to 6.66 in favor of the attacker -- the commitment of the small US corps reserve had little effect on the outcome -- and a Soviet breakthrough occurred early in this phase. During this phase (H+36-H+60) Soviet forces advanced at a rate of 43.06 kilometers per day at 1.80 kilometers per hour, thus penetrating the US corps' rear boundary at about H+43.

*Armored Reconnaissance Vehicles.

Case 2: Main Effort, Surprise v. Fortified Defense, Conventional

Table 4-2 shows the computer-generated engagement outcomes of combat in the CFA and MBA, postulating a Soviet main effort surprise attack versus a US fortified defense in the MBA. The average daily rate of advance, including the high rate for combat in the unfortified CFA, is 8.02 kilometers. Average daily personnel casualties were 398 men or 0.64% for the attacker and 778 men or 2.71% for the defender. Average daily tank losses were 77 tanks or 6.34% for the attacker and 92 tanks or 15.21% for the defender. Average personnel casualties per kilometer advanced or retreated were 0.08% for the attacker and 0.34% for the defender. Average tank losses per kilometer were 0.79% for the attacker and 1.90% for the defender.

The table shows that the fortified defense and the commitment of US reinforcements slowed the Soviet advance to the negligible rate of 0.94 kilometers per day in the period H+24 - H+36 (0.47 kilometers during the 12-hour period). In the ensuing 24-hour period, the commitment of the Soviet second echelon increased the combat power ratio in favor of the Soviets to the extent that they were able to advance more quickly -- 2.92 kilometers per day -- but, significantly, no breakthrough occurred. The Soviets, at H+60, penetrated 3.39 kilometers into the US corps MBA, still over 14 kilometers short of their breakthrough goal.

A comparison of engagement outcomes in Case 2 with those of Case 1 shows the following:

1. Fortifications reduced the average daily Soviet advance rate by a factor of 0.31 for the overall engagement. Excepting the combat in the CFA, however, fortifications reduced the average daily Soviet advance rate for the period by a factor of 0.07.

2. Fortifications increased the attacker's average daily personnel casualties by a factor of 1.78; the defender's average daily personnel casualties increased by a factor of 1.57.

3. Fortifications increased the average daily tank losses of the attacker by a factor of 1.78; the defender's average daily armor losses increased by a factor of 1.44.

Table 4-2. The effects of fortifications: Fulda Gap, c. 1980

Conventional Soviet Main Effort v. U.S. Fortified Defense*

Dates	Days		Personnel Strength	Cas	%/day	Cum	Tanks Strength	Losses	%/day	Cum	Distance km	/day	Cum	% Cas /km	% Tanks /km
D-Day	1	A	46,784	184	0.39	184	973	37	3.80	37	16.67	16.67	16.67	0.02	0.23
		D	11,455	268	2.34	268	469	74	15.78	74				0.14	0.95
H+24 to H+36	0.50	A	46,600	217	0.93	401	936	42	8.97	79	0.47	0.94	17.14	0.99	9.54
		D	34,462	496	2.88	764	716	53	14.80	127				3.06	15.74
H+36 to H+60	1.0	A	85,033	595	0.70	996	1,680	113	6.73	192	2.92	2.92	20.06	0.24	2.30
			42,893	1,182	2.76	1,946	788	104	13.20	231				0.95	4.52
Average	1.0	A	61,869	398	0.64		1,215	77	6.34		8.02			0.08	0.79
		D	28,692	778	2.71		605	92	15.21					0.34	1.90

*Covering force battle, delay posture

4. Fortifications increased the average personnel casualties per kilometer by a factor of 8.00 for the attacker and 4.86 for the defender.

5. Fortifications increased the average tank losses per kilometer by a factor of 5.64 for the attacker and 4.63 for the defender.

6. Fortifications increased the combat power of the defender to the extent that no breakthrough is indicated after 60 hours of combat, including 24 hours of combat subsequent to the commitment of the powerful Soviet second echelon. Breakthrough against the hasty defense required just 43 hours of combat.

Case 3: Main Effort, Surprise v. Hasty Defense, Nuclear Exchange

Cases 3 and 4 postulate the use of tactical nuclear weapons by both sides. The Soviet force was assumed to resort first to tactical nuclear weapons against the US force at H+36. After a 12-hour period of combat, during which the Soviets received the benefit of substantial surprise for the first employment of tactical nuclear weapons, the US corps replied with a tactical nuclear strike of its own, thus creating a battlefield nuclear exchange. The US tactical nuclear strike comprised a package of 90 representative US tactical nuclear weapons. Although the effects of the US tactical nuclear strike are presumed not to generate surprise, they have a substantial effect upon WP forces because of their density, and the lethality of the modernized weapons.

In both cases, the tables reflect the assumption of the particular variant at H+36, the point at which the Soviets first employ tactical nuclear weapons. The cumulative personnel casualties and tank losses shown at that point include the aggregate personnel casualties and tank losses in the conventional warfare variants (Cases 1 and 2) to that point. Also, as in Cases 1 and 2, the Soviet second echelon force is committed at H+36; in the cases at hand, it is assumed that the second echelon would be committed as soon as practicable subsequent to the Soviet tactical nuclear strike.

Table 4-3 shows the computer-calculated engagement outcomes of a Soviet main effort attack with surprise and tactical nuclear exchange versus a US hasty defense. The attacker's average daily rate of advance

Table 4-3. The effects of fortifications:
Fulda Gap, c. 1980

Nuclear Exchange* Soviet Main Effort vs. U.S. Hasty Defense

		Personnel			Tanks				Distance			%Cas	%Tank
Time/Event		Strength	Cas	%/Day	Cum	Strength	Losses	%/Day	Cum	KM	/Day	Cum	/KM	/KM
H+36 Sov Nuke	A	85,120			314	1,699			62			20.77		
(0.00 hours)	D	43,103	2,195	5.09	2,749	810	54	6.67	159					
H+36-D+2	A	85,120	73	0.17	387	1,699	14	1.65	76	24.34	48.67	45.11	0.010	0.04
(12 hours)	D	40,908	941	4.60	3,690	756	188	49.74	347				0.120	1.33
D+2 US Nuke	A	85,047	13,651	16.05	14,038	1,685	352	20.87	428					
(0.00 hours)	D	39,967			3,690	568			347					
D+2-H+60	A	71,396	40	0.11	14,078	1,333	4	0.60	432	18.72	37.44	63.83	0.003	0.02
(12 hours)	D	39,967	705	3.53	4,395	568	74	26.06	421				0.090	0.70
Average 1.0	A	59,279	5,631	9.50		1,172	173	14.76		25.53			0.370	0.58
	D	27,865	1,758	6.31		574	168	29.27					0.250	1.15

*Conventional weapons only for first 36 hours; 24 hours delay posture, 12 hours hasty-defense posture.

is 25.53 kilometers, which duplicates the rate achieved in case 1, the conventional warfare hasty defense variant. These figures are identical because, given the combat power ratios involved, with or without the employment of tactical nuclear weapons, the Soviet force will advance at the maximum daily rate allowable under the QJM rules against the hasty defense. The average daily personnel casualties were 9.50% for the attacker and 6.31% for the defender. These figures represent increases by factors of 26.39 and 3.65 respectively over the same figures for Case 1. (97% of Soviet casualties and 50% of US casualties are attributable to the effects of tactical nuclear weapons). The average daily tank losses were 14.76 for the attacker and 29.97% for the defender. These figures represent increases by factors of 4.15 and 2.77 over the same figures for Case 1. (81% of Soviet tank losses and 13% of US tank losses were caused by the effects of tactical nuclear weapons). Average personnel casualties per kilometer were 0.37% for the attacker and 0.25% for the defender. Average tank losses per kilometer were 0.58% for the attacker and 1.15% for the defender. The use of tactical nuclear weapons has, therefore, increased the human and material cost per kilometer by factors of 37.00 and 3.57 for attacker's and defender's personnel respectively and by factors of 4.14 and 2.80 for attacker's and defender's armor respectively, compared to the conventional warfare hasty defense variant.

Case 4: Main Effort, Surprise v. Fortified Defense, Nuclear Exchange

Table 4-4 shows the computer-generated engagement outcomes, postulating a Soviet main effort surprise attack with a nuclear exchange versus a US fortified defense. The average daily advance rate is 11.16 kilometers, which indicates that in this variant, following the nuclear exchange, the Soviets would have penetrated the US corps defensive area to a depth of 11.23 kilometers, ending their advance at H+60 some 6.27 kilometers short of their breakthrough goal. Average daily personnel casualties are 9.74% for the attacker and 6.26% for the defender. These figures represent increases by factors of 15.22 and 2.31 respectively over the same figures for Case 2, the conventional warfare fortified defense variant. Average daily tank losses are 15.58% for the attacker and 32.92 for the defender. These figures represent increases by factors of 2.46 and 2.16

Table 4-4. The effects of fortifications: Fulda Gap, c. 1980

Nuclear Exchange* Soviet Main Effort v. U.S. Fortified Defense

		Personnel				Tanks				Distance			%Cas	%Tanks
Time/Event		Strength	Cas	%/Day	Cum	Strength	Losses	%/Day	Cum	KM	/Day	Cum	/KM	/KM
H+36 Sov Nuke	A	85,033			401	1,680			79			17.14		
(0.00 hours)	D	42,893	1,571	3.66	2,335	788	38	4.82	165					
H+36-D+2	A	85,033	73	0.17	474	1,680	14	1.67	93	6.08	12.17	23.22	0.01	0.14
(12 hours)	D	41,322	949	4.59	3,284	750	186	49.60	351				0.38	4.08
D+2 US Nuke	A	84,960	13,885	16.34	14,359	1,666	354	21.25	447					
(0.00 hours)	D	40,373			3,284	564			351					
D+2-H+60	A	71,075	59	0.17	14,418	1,312	5	0.76	452	4.68	9.36	27.90	0.02	0.08
(12 hours)	D	40,373	1,069	5.30	4,353	564	110	39.00	461				0.57	4.17
Average	A	59,185	5,767	9.74		1,162	181	15.58		11.16			0.87	1.40
	D	27,810	1,741	6.26		559	184	32.92					0.56	2.95

*Conventional weapons only for first 36 hours; 24 hours delay posture, 12 hours fortified defense posture.

over the same figures for Case 2. Average casualties per kilometer are 0.87% for the attacker and 0.56% for the defender, increases by factors of 10.88 and 1.65 respectively over the same figures for case 2. Average tank losses per kilometer are 1.40% for the attacker and 2.95% for the defender, increases by factors of 1.77 and 1.55 respectively over the same figures for case 2.

A comparison of Case 4 with Case 3 shows the following:

1. Fortifications reduced the average daily Soviet advance rate by a factor of 0.44 for the overall engagement. Excepting the combat in the unfortified CFA, fortifications reduced the average daily Soviet advance rate by a factor of 0.24.

2. Fortifications increased the attacker's average daily personnel casualties by a factor of 1.03 but decreased the defender's average daily personnel casualties by a factor of 0.99.

3. Fortifications increased the average daily tank losses of both the attacker and the defender by factors of 1.06 and 1.12 respectively.

4. Fortifications increased the average personnel casualties per kilometer for the attacker and the defender by factors of 2.35 and 2.24 respectively.

5. Fortifications increased the average tank losses per kilometer for the attacker and the defender by factors of 2.41 and 2.57 respectively.

6. Fortifications increased the combat power of the defender to the extent that no breakthrough is indicated after 60 hours of combat, including a nuclear exchange and the commitment of the Soviet second echelon.

CHAPTER V

ANALYSIS

SUMMARY OF THE METHODOLOGY

The bases of comparison -- or measures of effectiveness - in testing the significance of field fortifications in this study are: (1) the distance advanced over time, (2) the casualties sustained, and (3) tank losses (both (2) and (3) over time and over distance).

Two sets of data have been used for this comparison. Group A comprises eight engagements of World War II and the October 1973 War, in which the outcomes (regardless of which side was successful) were clearly influenced by each defender's use of fortifications. Group B comprises six engagements from those same wars in which the defensive posture was essentially a hasty or mobile defense (even though some prepared defenses may have been present). The steps of the analysis were:

1. In each of the eight engagements of Group A, the results of a QJM analysis, replicating the historical battle, were compared to the historical data in the following respects.

    a. Percent casualties per day for attacker and defender;
    b. Percent tank losses per day for attacker and defender.
    c. Advance rate of the attacker in kilometers per day;
    d. Percent casualties per kilometer for attacker and defender;
    e. Percent tank losses per kilometer for attacker and defender.

2. For each of the Group A engagements an alternative QJM analysis was performed, with all conditions the same as those in the historical battle, except that the defender relied only upon a hasty or mobile defense. The results of this analysis were then compared with the historical data and the results of the QJM replication of it.

3. For each of the six engagements of Group B (hasty-prepared-mobile defense posture) a QJM replication of the historical data was performed, following the procedures of Step 1.

4. For Group B the same kind of alternative posture analysis was performed for Step 2, except that in these six cases the alternative postures were fortified defense.

5. The results of the QJM replications for Groups A and B were compared with the historical data.

6. The results of the QJM analysis for replications and alternative postures for Group A were compared with each other; a similar comparison was done for Group B; these two sets of comparisons were then compared with each other.

7. An extrapolation of the comparative historical analysis was applied to a hypothetical surprise Warsaw Pact offensive against the US V Corps in the Fulda Gap in the early 1980's (with conventional weapons only employed by both sides) in two scenarios, one with the defender in a hasty-mobile defense posture, the other with a fortified defense.

8. A similar extrapolation was made for a hypothetical Warsaw Pact surprise attack against the US V Corps in the Fulda Gap in the 1980's, this time postulating that Pact forces would employ tactical nuclear weapons in an effort to insure a breakthrough, with a response in kind by NATO.

9. The implications of the preceding analysis were summarized in the following respects:

a. General implications

b. Operational implications for NATO

c. Research requirements

COMPARISON OF HISTORICAL DATA WITH QJM REPLICATIONS

The results of Steps 1 to 5 are displayed in Table 5-1, which shows the comparison between the historical data and the QJM replications. The correlation, as is readily evident, is close.

This is a small sample, and a statistical analysis could easily be seriously affected if the data for any one engagement deviates substantially from the average. To test the effect of this in each category, a sensitivity analysis was performed on the eight engagements of Group A, eliminating from each comparison of historical over replication the engagement which included the data for one of the combatants that varied most above or below the average. The results of this test for the eight engagements of Group A are shown below. In each instance the left hand column or figure is the average of the ratios, the right hand figure is the result of the elimination

test. The figure in parentheses below the right column shows its deviation from the average.

A-1. Omitting the engagements with deviations farthest below average in each category:

Average	Casualties		Tank Losses		Km/day		%Cas/km		%Tk loss/km	
Attacker	1.26	1.32	1.14	1.23	1.32	1.40	1.14	1.23	1.01	1.08
Defender	1.40	1.49	1.76	1.99		(1.06)	1.22	1.32	1.04	1.67
Composite	1.33	1.41	1.45	1.61			1.18	1.28	1.24	1.38
		(1.06)		(1.11)				(1.08)		(1.11)

A-2. Omitting the engagements with deviations farthest above average in each category:

Average	Casualties		Tank Losses		Km/day		%Cas/km		% Tk loss/km	
Attacker	1.26	1.10	1.14	1.23	1.32	1.19	1.14	0.85	1.01	0.77
Defender	1.40	1.28	1.76	1.41		(0.90)	1.22	0.97	1.47	1.28
Composite	1.33	1.16	1.45	1.31			1.18	0.92	1.24	1.03
		(0.57)		(0.90)				(0.78)		(0.83)

This process yields a range in values for each of these comparative categories. Deviation of replication casualties from historical casualties, for example, ranges from 1.11 to 1.49, and tank losses from 1.21 to 1.99.

Table 5-1 shows that the advance rates and casualty rates calculated by the QJM tend to be somewhat lower on the average than the historical rates. In only one instance, the defender's tank losses at Seelow Heights, is there a significant difference, 3.86. (For a number of reasons, the data in that engagement may be less reliable than the data for other engagements.) In no case does the average exceed 1.99. In view of the fact that exceptional circumstances in any battle may cause the advance or casualty rate of the opponents to deviate substantially from normal, the correlations in this sample may be considered excellent.

A similar analytical test of the six engagements of Group B gave the following results:

B-1. Omitting the engagements with deviations farthest below average:

Average	Casualties		Tank Losses		Km/day		%Cas/km		% Tk loss/km	
Attacker	1.24	1.28	1.00	1.16	1.09	1.14	1.16	1.15	0.86	0.97
Defender	1.26	1.32	1.21	1.25		(1.05)	1.22	1.31	1.15	1.17
Composite	1.25	1.30	1.11	1.21			1.19	1.23	1.01	1.07
		(1.06)		(1.09)				(1.03)		(1.06)

B-2. Omitting the engagements with deviations highest above the average:

Average	Casualties		Tank Losses		Km/day		%Cas/km		% Tk loss/km	
Attacker	1.24	1.17	1.00	0.75	1.09	1.01	1.16	1.17	0.86	0.72
Defender	1.26	1.29	1.21	1.08		(0.93)	1.22	1.06	1.15	1.12
Composite	1.25	1.23	1.11	0.92			1.19	1.12	1.01	0.92
		(0.98)		(0.83)				(0.94)		(0.91)

Table 5-1. Comparisons of historical data with QJM replications

A. Examples of Historical Fortified-Prepared Postures

		Casualties			Tank Losses			Distance/day			%.Casualties/km			% Tank Loss/km		
		Hist %	Repl %	Hist/Repl	Hist %	Repl %	Hist/Repl	Hist km	Repl km	Hist/Repl	Hist	Repl	Hist/Repl	Hist	Repl	Hist/Repl
Kursk P.	A	0.99	0.83	1.19	8.88	6.23	1.43	3.74	1.69	2.21	0.26	0.49	0.53	2.37	3.69	0.64
	D	3.14	2.74	1.15	11.06	15.51	0.71				0.84	1.62	0.52	2.96	9.18	0.32
Kursk O.	A	1.12	0.75	1.49	8.99	5.90	1.52	2.58	1.41	1.83	0.43	0.53	0.81	3.48	4.18	0.83
	D	2.28	1.63	1.40	10.68	8.63	1.24				0.88	1.16	0.76	4.14	6.12	0.68
Nikopol	A	0.41	0.46	0.89	12.50	7.33	1.71	1.00	1.04	0.96	0.41	0.44	0.93	12.50	7.05	1.77
	D	0.31	0.42	0.74	-	-	-				0.31	0.40	0.78	-	-	-
Bowling Alley	A	1.36	1.22	1.11	6.97	13.46	0.52	1.52	1.49	1.02	0.89	0.82	1.09	4.59	9.03	0.51
	D	2.34	2.48	0.94	7.98	24.38	0.33				1.54	1.66	0.93	5.25	16.36	0.32
Westwall	A	0.76	0.83	0.92	4.17	6.65	0.63	1.26	1.00	1.26	0.60	0.83	0.72	3.31	6.65	0.50
	D	3.16	1.41	2.24	22.22	10.40	2.14				2.51	1.41	1.78	17.63	10.40	1.70
Seelow	A	1.74	1.71	1.02	34.62	51.56	0.67	1.13	0.71	1.59	1.54	2.41	0.64	30.64	72.62	0.72
	D	2.05	1.36	1.51	42.86	11.11	3.86				1.81	1.92	0.94	37.93	15.65	2.42
Suez (N)	A	0.82	0.72	1.14	11.76	17.65	0.67	0.84	0.91	0.92	0.98	0.79	1.24	14.00	19.40	0.72
	D	2.92	2.94	0.99	52.24	25.37	2.06				3.48	3.23	1.08	62.19	27.88	2.23
Ahmadiyeh	A	3.93	1.67	2.35	96.97	49.15	1.97	0.57	0.77	0.74	6.89	2.17	3.18	170.12	63.83	2.67
	D	3.76	1.70	2.21	29.58	15.07	1.96				6.60	2.21	2.99	51.89	19.57	2.65
Ratio Averages				1.26			1.14			1.32			1.14			1.01
				1.40			1.76						1.22			1.47
Posture				1.33			1.45						1.18			1.27
Averages	A	1.39	1.02	1.43	23.11	19.74	21.43	1.58	1.13	1.40	1.50	1.06	1.28	30.11	23.31	26.71
	D	2.50	1.84	1.36	75.73	15.78	20.51				2.25	1.70	1.98	26.00	15.02	20.51
Composite Avgs				1.40			20.97						1.63			21.61

B. Examples of Historical Hasty-Prepared Postures

Aprilia	A	0.64	0.62	1.03	2.89	3.72	0.78	2.40	2.81	0.85	0.27	0.22	1.23	1.20	1.32	0.91
	D	0.73	0.76	0.96	4.44	3.33	1.33				0.30	0.27	1.11	1.85	1.19	1.55
Terracina	A	0.53	0.56	0.95	3.23	6.91	0.48	2.68	3.20	0.84	0.20	0.18	1.11	1.21	2.16	0.56
	D	1.93	1.15	1.68	8.00	6.00	1.33				0.72	0.36	2.00	2.99	1.88	1.59
Valmontone	A	1.35	1.05	1.29	2.50	9.56	0.26	2.60	2.70	0.96	0.52	0.39	1.33	0.96	3.54	0.27
	D	2.85	2.04	1.40	13.33	13.33	1.00				1.10	0.76	1.45	5.13	4.94	1.04
Sauer	A	1.35	1.12	1.21	28.57	29.00	0.99	3.17	2.87	1.10	0.43	0.39	1.10	9.01	10.10	0.89
	D	0.78	0.63	1.24	2.56	4.37	0.59				0.25	0.22	1.14	0.81	1.52	0.53
Jebel Geneifa	A	0.62	0.46	1.35	3.14	2.52	1.25	14.30	10.94	1.31	0.04	0.04	1.00	0.22	0.23	0.96
	D	1.54	1.38	1.16	8.37	7.42	1.13				0.11	0.13	0.85	0.59	0.67	0.88
Tel Fars	A	0.84	0.53	1.58	7.23	3.21	2.28	12.00	8.19	1.47	0.07	0.06	1.17	0.60	0.39	1.54
	D	1.53	1.43	1.10	15.42	8.30	1.86				0.13	0.17	0.76	1.29	1.01	1.28
Ratio averages				1.24			1.01			1.09			1.16			0.86
				1.26			1.21						1.22			1.15
				1.25			1.11						1.19			1.01
Posture Avgs.	A	0.89	0.72	0.81	7.93	9.15	8.54	6.19	5.14	1.20	0.26	0.21	0.24	2.20	2.96	2.58
	D	1.57	1.23	1.40	8.69	7.13	7.91				0.44	0.32	0.38	2.11	1.87	1.99
Composite Avgs.				1.11			8.23						0.31			2.29

As was the case with Group A, the correlation between the historical data and the QJM replications is very close, whether the figures in Table 5-1 or the range of averages shown above are used.

In summary, inspection of the figures in Table 5-1 and the average ranges in A and B show that (at least for this small sample):

1. QJM replications, whether for fortified-prepared postures or hasty-prepared postures, are reasonably close replications of historical data.

2. On the average, QJM replications for attacker's and defender's casualties and tank losses in a fortified-prepared situation are low by factors of about 1.33 and 1.45 respectively.

3. On the average, QJM replications for attacker's advance rates in a fortified-prepared situation are low by a factor of about 1.24.

4. On the average, QJM replications for attacker's and defender's casualties and tank losses in a hasty-prepared situation tend to be low by a factor of 1.22 and high by a factor of 1.18 (reciprocal of 0.85), respectively.

5. On the average, QJM replications of attacker's advance rates in a hasty-prepared defense situation tend to be low by a factor of 1.06 (reciprocal of 0.94).

Adjustment of the Constant Factors

The attrition and advance rate submodels of the QJM are the most recent refinements of a methodology that was first evolved about 1971 and has been constantly refined since that time. These new attrition advance rates were first presented publicly in a MORS paper* in 1977, and have themselves been slightly modified since.**

The deviations of the QJM generated rates from historical rates for these 14 examples may or may not reflect the need for refinement in the

* T.N. Dupuy, "Realistic Attrition and Advance Rates for Combat Simulations and Planning," delivered at 40th MORS, 14 December 1977.

**Most notably in HERO Report, The Effects of Combat Losses and Fatigue on Operational Performance, January 1979.

formulae or in the empirically-derived constants contained in those formulae. This can be ascertained, of course, only after a painstaking analysis of the entire HERO combat data base, now about 150 modern engagements from 1940 through 1973.

What is clear from the data shown in Figure 5-1 and the sensitivity analyses presented above, is that the QJM attrition and advance rate formulae closely approximate the average rates found in this limited sample of fourteen engagements. To facilitate a comparison of historical engagement data with hypothetical engagement data by means of the QJM, however, it is desirable that the data derived from QJM replications of the historical engagements, whether fortified or hasty-mobile, correspond as closely as possible to the historical data. This can be accomplished by adjustment (for this study only, pending more exhaustive research) of the constant (or K) factors in the current QJM attrition and advance formulae, as shown on Table 5-2. Table 5-3 shows the result of the application of these modified K factors results in a correspondence of overall casualty and tank loss rates (attacker and defender, both postures) within 11 percent. Given the fact that data reliability is probably less than $\pm$ 10 percent, and that casualty and advance factors frequently vary from norms by factors of 100 percent or more, further refinements for the purposes of this study do not appear reasonable. Table 5-4 presents a summary of the data in Table 5-3.

It is therefore safe to assert that, as adjusted, the advance and attrition rates for the QJM samples are reasonable, extremely faithful, replications of the actual historical rates.

Furthermore, it should be noted that the application of these adjusted QJM rate factors make absolutely no difference in the analysis and conclusions of this study, and only slight difference in the specific factors for the effects of fortifications which emerge from the analysis. The purposes of making this adjustment are twofold:

1. To demonstrate the flexibility and utility of the methodology, and
2. To avoid unnecessary, tangential debate about whether the QJM does or does not replicate the historical data of this sample.

Table 5-2. QJM Advance and Attrition Constant Factors

		Original K	Tentative New K *	Factor
Casualty Rate,	Attacker/day	0.030	0.037	1.25
	Defender/day	0.030	0.039	1.33
Tank Loss Rate	Attacker/day	6.00	4.90	0.82
	Defender/day	3.00	3.18	1.06
Advance Rate, Km/day		1.00	1.24	1.24

*Based on this sample; to be tested against data base.

Table 5-3. Comparisons of Historical Data with Adjusted QJM Data

A. Historical Fortified-Prepared Postures

		Personnel			Tanks			Distance/day			% Casualties/km			%Tank Loss/km		
		Hist	New Repl	Hist /Repl	Hist	New Repl	Hist /Repl	Hist km	Repl km	Hist/Repl	Hist	New Repl	Hist /Repl	Hist	New Repl	Hist /Repl
Kursk P	A	0.99	1.04	0.95	8.88	6.38	1.39	3.74	2 10	1.78	0.24	0.50	0.52	2.37	3.04	0.78
	D	3.14	3.64	0.86	11.06	21.89	0.51				0.84	1.73	0.49	2.96	10.42	0.28
Kursk O	A	1.12	0.94	1.19	8.99	6.03	1.49	2.58	1.75	1.47	0.43	0.54	0.80	3.48	3.45	1.01
	D	2.28	2.17	1.05	10.68	10.89	0.98				0.88	1.24	.71	4.14	6.22	0.67
Nikopol	A	0.41	0.58	0.71	12.50	7.50	1.67	1.00	1.29	0.78	0.41	0.45	0.91	12.50	5.81	2.15
	D	0.31	0.56	0.55	--	--	--				0.31	0.43	0.72	--	--	--
Bowling	A	1.36	1.5?	0.89	6.97	13.78	0.51	1.52	1.85	0.82	0.89	0.83	1.07	4.59	7.45	0.62
Alley	D	2.34	3.?0	0.71	7.98	35.67	0.22				1.54	1.78	0.87	5.25	19.28	0.27
Westwall	A	0.76	1.0?	0.73	4.17	6.81	0.61	1.26	1.24	1.02	0.60	0.84	0.71	3.31	5.49	0.60
	D	3.14	1.88	1.67	22.22	14.68	1.51				2.51	1.52	1.66	17.63	11.84	1.49
Seelow	A	1.74	2.14	0.81	34.12	52.76	0.66	1.13	0.89	1.28	1.54	2.43	0.63	30.64	59.95	0.51
	D	2.05	1.81	1.13	42.86	15.67	2.74				1.81	2.06	0.88	37.93	17.81	2.13
Suez N	A	0.82	0.90	0.91	11.76	18.06	0.65	0.84	1.13	0.74	0.98	0.80	1.23	14.00	15.98	0.88
	D	2.92	3.91	0.75	52.24	35.80	1.46				3.48	3.46	1.01	62.19	31.68	1.96
Ahmadiyeh	A	3.93	2.09	1.88	96.97	50.30	1.93	0.57	0.95	0.60	6.89	2.20	3.13	170.12	52.95	3.21
	D	3.76	2.26	1.66	29.58	21.27	1.39				6.60	2.38	2.72	51.89	22.34	2.32
Ratio	A			1.01			1.11						1.13			1.22
Average	D			1.05			1.26						1.14			1.30
				1.03			1.19						1.14			1.26
Posture	A	1.39	1.28	1.09	23.11	20.20	1.14	1.58	1.40	1.13	1.50	1.07	1.40	30.13	19.27	1.56
Average	D	2.50	2.44	1.02	25.23	22.27	1.13				2.25	1.83	1.23	26.00	17.08	1.52
Composite Average				1.06			1.14						1.32			1.54

B. Historical Hasty-Prepared Postures

Aprilia	A	0.64	0.78	0.82	2.89	3.81	0.76	2.40	3.48	0.69	0.27	0.22	1.23	1.20	1.09	1.10
	D	0.73	1.01	0.72	4.44	4.70	0.94				0.30	0.29	1.03	1.85	1.35	1.37
Terracina	A	0.53	0.70	0.76	3.23	7.07	0.46	2.68	3.97	0.68	0.20	0.18	1.11	1.21	1.78	0.68
	D	1.93	1.53	1.26	8.00	8.47	0.94				0.72	0.39	1.85	2.99	2.13	1.40
Valmontone	A	1.35	1.31	1.03	2.50	9.88	0.25	2.60	3.35	0.78	0.52	0.31	1.68	0.96	2.94	0.33
	D	2.85	2.71	1.05	13.33	18.81	0.71				1.10	0.81	1.36	5.13	5.61	0.91
Sauer River	A	1.35	1.40	0.96	28.57	29.68	0.96	3.17	3.56	0.89	0.43	0.39	1.10	9.01	8.34	1.08
	D	0.78	0.84	0.93	2.56	6.16	0.42				0.25	0.24	1.42	0.81	1.73	0.47
Jebel	A	0.62	0.58	1.07	3.14	2.58	1.22	14.30	13.57	1.05	0.04	0.04	1.00	0.22	0.19	1.16
Geneifa	D	1.54	1.84	0.84	8.37	10.47	0.80				0.11	0.14	0.79	0.59	0.77	0.76
Tel Fars	A	0.84	0.66	1.27	7.23	3.27	2.21	12.00	10.16	1.18	0.07	0.06	1.17	0.60	0.32	1.88
	D	1.58	1.90	0.83	15.42	11.72	1.32				0.13	0.19	0.68	1.29	1.15	1.12
Ratio				0.99			0.85						1.23			1.04
Average				0.94									1.19			1.01
				0.97									1.21			1.03
Posture	A	0.89	0.90	0.99	7.93	9.30	0.87	6.19	6.35	0.97	0.26	0.20	1.30	2.20	2.44	0.90
Average	D	1.57	1.64	0.96	8.69	10.00					0.44	0.34	1.29	2.11	2.12	1.00
Composite Average				0.98			0.86						1.30			0.95

Table 5-4. Summary of comparisons of historical data with adjusted QJM replication

Advance & Attrition Rates

	Distance/Day				% Casualties/Day			% Tank Losses/Day		
	Hist (Km)	Repl (Km)	Hist /Repl		Hist	Repl	H/R	Hist	Repl	H/R
A. Examples of Historical Fort-Prep Posture	1.58	1.40	1.13	Atkr	1.39	1.28	1.09	23.11	20.20	1.14
				Dfdr	2.50	2.44	1.02	25.23	22.27	1.13
							1.06			1.14
B. Examples of Historical Hasty-Prep Posture	6.19	6.35	0.97	Atkr	0.89	0.90	0.99	7.93	9.30	0.85
				Dfdr	1.57	1.64	0.96	8.69	10.06	0.86
							0.98			0.86

		% Casualties/Km			% Tank Loss/Km		
		Hist	Repl	H/R	Hist	Repl	H/R
A. Examples of Historical Fortified-Prepared	Atkr	1.50	1.07	1.40	30.13	19.26	1.56
	Dfdr	2.25	1.93	1.23	22.75	15.66	1.45
				1.32			1.51
B. Examples of Historical Hasty-Prepared	Atkr	0.26	0.21	1.24	2.20	2.61	0.84
	Dfdr	0.44	0.34	1.29	2.11	2.20	0.96
				1.27			0.90

COMPARISONS OF DELAY AND CASUALTY EFFECTIVENESS OF ALTERNATIVE POSTURES

Since the historical results and the results of QJM replications of the engagements are closely correlated, it is assumed that a comparison of actual engagements with hypothetical engagements (both analyzed by the QJM) in which posture is the only condition that has been changed, would be valid. The data generated by the QJM replication of the historical engagements is compared in Table 5-5 with QJM calculations of the hypothetical engagements -- which are the same engagements with a change in the defense condition.

As was done with the data presented in Table 5-1, a similar kind of sensitivity analysis was performed with the data in Table 5-5.

The comparability of the relationship of the data columns for the two postures in both groups was confirmed by very minor deviations from the averages in sensitivity analysis. Therefore, the data can be presented in terms of the principal measures of effectiveness (rates of advance and attrition rates per day and per kilometer) as shown in Table 5-6, and summarized in Table 5-7, which present the effects of fortifications on these measures of effectiveness as follows:

o Advance rates are reduced by a factor of 0.13 (or its reciprocal, 7.46)

o Breakthrough time is increased from 2.03 days (13 instances) to 5.95 days (8 instances) or 293%, for an average saving of 4 days

o Attacker's casualties/km are increased by a factor of 8.0

o Attacker's tank losses/km are increased by a factor of 6.2

o Defender's casualties/km are increased by a factor of 6.0

o Defender's tank losses/km are increased by a factor of 3.6

A similar comparison of the daily attrition rates (personnel and tanks) gives the following interesting results:

o Attacker's daily casualty rate is increased by a factor of 1.3

o Attacker's daily tank loss rate is increased by a factor of 1.4

o Defender's daily casualty rate is decreased by a factor of 0.8

o Defender's daily tank loss rate is decreased by a factor of 0.7

Thus, a defender can expect a slight decrease in casualties over time (although an overall increase in casualties over distance) and can expect to inflict substantially greater casualties on the attacker over both time and distance. But the principal benefit of fortifications to the defender

Table 5-5. Comparisons of Delay and Casualty Effectiveness of Fortified-Prepared Postures and Hasty-Prepared Postures Based on OJM Calculated Data

A. Examples of Historical Fortified-Prepared Postures

		Casualties			Tank Losses			Distance/day			%Casualties/km			%Tanks/km		
		FP%	HP%	FP/HP	FP%	HP%	FP/HP	FP km	HP km	FP/HP	FP%	HP%	FP/HP	FP%	HP%	FP/HP
Kursk P	A	0.83	0.92	0.90	6.23	9.26	0.67	1.69	22.10	0.07	0.49	0.04	12.25	3.69	0.42	8.79
	D	2.74	3.89	0.70	15.51	0.00	∞				1.62	0.18	9.00	9.18	0.00	-
Kursk O	A	0.75	0.24	3.13	5.90	2.52	2.34	1.41	30.03	0.05	0.53	0.01	53.00	4.18	0.08	52.25
	D	1.63	2.77	0.59	8.63	44.63	0.19				1.16	0.09	12.89	6.12	1.49	4.11
Nikopol	A	0.46	0.43	1.07	7.33	9.09	0.81	1.04	2.07	0.51	0.44	0.21	2.10	7.05	4.39	1.61
	D	0.42	0.43	0.98	-	-	-				0.40	0.21	1.90	-	-	-
Bowling Alley	A	1.22	1.04	1.17	13.46	10.82	1.24	1.49	2.98	0.50	0.82	0.35	2.34	9.03	3.63	2.49
	D	2.48	2.82	0.88	24.38	23.19	1.05				1.66	0.95	1.75	16.36	7.78	2.10
Westwall	A	0.83	1.26	0.66	6.65	18.51	0.36	1.00	4.46	0.22	0.83	0.28	2.96	6.65	4.15	1.60
	D	1.41	1.71	0.83	10.40	10.53	0.99				1.41	0.38	3.71	10.40	2.36	4.41
Seelow	A	1.71	1.17	1.46	51.56	22.58	2.28	0.71	10.37	0.07	2.41	0.11	21.91	72.62	2.18	33.31
	D	1.36	3.49	0.39	11.11	20.00	0.56				1.92	0.34	5.65	15.65	1.93	8.11
Suez (N)	A	0.72	0.81	0.89	17.65	29.41	0.60	0.91	2.40	0.38	0.79	0.34	2.32	19.40	12.25	1.58
	D	2.94	2.94	1.00	25.37	43.28	0.59				3.23	1.23	2.63	27.88	18.03	1.55
Ahmadiyeh	A	1.67	1.03	1.62	49.15	27.91	1.76	0.77	5.19	0.15	2.17	0.20	10.85	63.83	5.38	11.86
	D	1.70	2.81	0.61	15.07	27.94	0.54				2.21	0.54	4.09	19.57	5.38	3.64
Posture Averages	A	1.28	1.10	1.16	20.20	16.59	1.22	1.40	11.89	0.12	1.07	0.19	5.63	19.26	4.13	4.66
	D	2.44	3.25	0.75	22.27	39.85	0.56				1.83	0.51	3.59	15.66	7.45	2.10
Ratio	A/D			1.55			2.18						1.57			2.22

B. Examples of Historical Hasty-Prepared Postures

Aprilia	A	0.60	0.62	0.97	4.58	3.72	1.23	0.43	2.81	0.15	1.40	0.22	6.36	10.65	1.32	8.07
	D	1.73	0.76	2.28	7.95	3.33	2.39				4.02	0.27	14.89	18.49	1.19	15.54
Terracina	A	0.48	0.56	0.86	3.57	6.91	0.52	0.73	3.20	0.23	0.66	0.18	3.67	4.89	2.16	2.25
	D	1.12	1.15	0.97	6.00	6.00	1.00				1.53	0.36	4.25	8.22	1.88	4.37
Valmontone	A	1.84	1.05	1.75	24.80	9.56	2.59	0.83	2.70	0.31	2.22	0.39	5.69	37.95	3.54	10.72
	D	1.16	2.04	0.58	10.00	13.33	0.75				1.42	0.76	1.87	12.05	4.94	2.44
Sauer R.	A	1.94	1.12	1.73	42.86	29.00	1.48	0.72	2.87	0.25	2.69	0.39	6.90	59.53	10.10	5.89
	D	0.49	0.63	0.78	2.59	4.37	0.59				0.68	0.22	3.09	3.60	1.52	2.37
Jelel Geneifa	A	0.94	0.96	2.04	5.29	2.52	2.08	1.83	10.74	0.17	1.54	0.04	38.50	8.59	0.23	37.35
	D	2.82	1.38	2.04	15.20	7.42	2.05				4.62	0.03	35.54	24.92	0.67	37.15
Tel Aviv	A	0.97	4.53	1.83	5.62	3.21	1.75	3.58	8.19	0.07	1.67	0.06	27.83	9.69	0.39	24.85
	D	1.46	1.43	1.02	8.30	8.30	1.00				2.57	1.07	2.15	14.32	1.01	14.17
Averages	A	1.39	0.90	1.54	14.74	9.30	1.58	1.05	6.35	0.17	2.13	0.21	10.14	22.39	2.61	8.58
	D	1.43	1.64	0.87	11.76	10.00	1.17				3.28	0.34	9.65	14.19	2.70	8.72
Ratio A/D				1.77			1.35						1.05			0.98

Table 5-6. Summary of comparisons of delay and casualty effectiveness of fortified-prepared and hasty-prepared postures I

Advance & Attrition Rates/Day

	Distance/Day (KM)				% Casualties/Day				% Tank Loss/Day		
	F-P	H-P	FP/HP		F-P	H-P	FP/HP		F-P	H-P	FP/HP
A. Examples of Historical Fort-Prep Posture	1.40	11.89	0.12	Atkr	1.28	1.10	1.16	Atkr	20.20	16.59	1.22
				Dfdr	2.44	3.25	0.75	Dfdr	22.27	39.85	0.56
						A/D	1.55			A/D	2.18
B. Examples of Historical Hasty-Prep Posture	1.05	6.35	0.17	Atkr	1.39	0.90	1.54	Atkr	14.74	9.30	1.58
				Dfdr	1.43	1.64	0.87	Dfdr	11.76	10.06	1.17
						A/D	1.77			A/D	1.35
C. Averages	1.23	9.12	0.13	Atkr	1.34	1.00	1.34	Atkr	17.47	12.95	1.35
			7.46	Dfdr	1.94	2.44	0.80	Dfdr	17.52	24.96	0.70
						A/D	1.68			A/D	1.69

Table 5-7. Summary of comparisons of delay and casualty effectiveness of fortified-prepared and hasty-prepared postures II

Advance & Attrition Rates/Km

			% Casualties/KM			% Tank Loss/KM		
			F-P	H-P	FP/HP	F-P	H-P	FP/HP
A.	Examples of Historical Fort-Prep Posture	A	1.07	0.19	5.63	19.26	4.13	4.66
		D	1.83	0.51	3.59	15.66	7.45	2.10
				A/D	1.57		A/D	2.22
B.	Examples of Historical Hasty-Prep Posture	A	2.13	0.21	10.14	22.39	2.61	8.58
		D	3.28	0.34	9.65	19.19	2.20	8.72
				A/D	1.05		A/D	0.98
C.	Averages	A	1.60	0.20	8.00	20.83	3.37	6.18
		D	2.56	0.43	5.95	17.43	4.83	3.61
				A/D	1.34		A/D	1.71

is the great gain in time. The examples in both Group A and Group B testify to the significance of this time benefit to the defender in terms of battle outcomes.

The following conclusions are drawn from the above:

1. Attacker's casualty rates per day and tank loss rates per day are both increased by factors of about 1.35 when the defender was in a fortified or semi-fortified posture, in comparison with a hasty or mobile defense posture.

2. Defender's casualty rates per day and tank loss rates per day decreased by factors of about 0.8 and 0.7 respectively in a fortified-prepared posture in comparison with a hasty or mobile defense posture.

3. The advance rate of the attacker against a fortified-prepared defense was decreased by a factor of about 0.13 in comparison with the rates against hasty-prepared defenses.

4. Percent casualties per kilometer of attackers against fortified-prepared defenses increased by a factor of about 8.0 over those against hasty-prepared defenses.

5. Percent tank losses per kilometer of attackers against fortified-prepared defenses increased by a factor of about 6.2 against hasty-prepared defenses.

6. The casualty and tank loss exchange ratio of attackers to defenders in terms of percent casualties per kilometer in fortified-prepared defense were increased on the average by factors of approximately 1.4 and 1.7 in comparison with the ratios in hasty-prepared defense.

Table 5-8 is a summary comparison of the effects on actual and hypothetical battle outcomes of fortified-prepared posture and hasty-prepared posture.

Although the historical data and QJM replication of daily advance and attrition rates are very close, analysis of a larger data base would be expected to produce even closer results. Aggregating successes and failures in calculating rates per kilometer probably has multiplied errors innate in the process which did not separate them. However, on the average the deviations do not exceed a factor of 1.56, which in view of the chance circumstances that cause great and often inexplicable variations in casualty rates between engagements is a remarkable correspondence.

Table 5-8. Effects of fortifications on battle outcomes

	Fortified Posture Results				Hasty Posture Results				
	N/N	PR/Pr	Attack Success (Days)	Outcome Failure	Days	PP/PR	Attack Success (Days)	Outcome Failure (Days)	Outcome Multiplier Fort Hasty
Group A (Historical/Hypothetical)									
Kursk, P	2.68	1.24		3.54[3]		3.81	1.36[1]	-	3.07
Kursk, O	1.19	0.82		8.00[3]		6.18	1.00[1]	-	7.54
Nikopol	3.05	0.74	9.00[2]		-	1.25	7.25[?]	-	1.69
Bowling Alley	2.05	0.72	-		4.00[4]	0.84	-	5	1.17
West Wall	1.76	1.2/	6.00[1]		-	1.86	1.30[1]	-	1.46
Seelow	3.65	1.17	1.30[2]		-	3.75	0.50[1]	-	3.21
Suez Canal (N)	5.50	1.94	0.42[3]		-	2.44	0.13[1]	-	1.26
Ahmadiyeh	3.94	0.33	-		1.42[4]	1.28	1.86[1]	-	3.88
Group B (Hypothetical/Historical)									
Aprilia	2.87	0.75	-		5	1.66	2.00[2]	-	2.21
Terracina	2.71	1.88	7.34[?]			2.09	2.00[1]	-	1.11
Valmontone	2.63	0.66	-		5	1.49	1.00[1]	-	2.26
Sauer R.	1.16	0.42	-		5	1.34	2.00[3]		3.19
Jebel Geneifa	0.45	0.71	-		5	2.87	3.00[1]	-	4.04
Tel Fars	0.75	1.13		12.00[?]		2.44	3.00[2]	-	2.16
Average			5.95 days				2.03 days		

[1]Breakthrough. [2]Defender withdrew. [3]Defender reinforcements prevent breakthrough.
[4]Attack failed. [5]Breakthrough unlikely.

STATISTICAL ANALYSIS

Although this is a small sample, a statistical analysis was performed. No attempt was made to analyze the relationship of historical data to the QJM replications or to the hypothetical alternative postures. The analysis was performed with respect to the attacker only.

The principal conclusion of the analysis is shown on the following table:

Attacker's Measures of Effectiveness	Type of Defense	
	Fortified	Hasty
km/day advance	1.6	6.2
% cas/km advance	1.5	0.3
% tank loss/km advance	30.1	2.2

Because of the small amount of data, such a conclusion must be presented cautiously, but it suggests that attacking a fortified position as compared to a hasty-defense position changes outcomes for the attacker as follows:

- o Casualties increased by a factor of 5
- o Tank losses increased by a factor of 13
- o Rate of advance was reduced by a factor of 0.26 (or its reciprocal, 4.0)

Table 5-9 is an expanded presentation of this analysis, modified to include the effects of the difference in posture upon the defender's attrition, and comparing these results to those of the QJM analysis presented above. It will be seen that the results of the two different analyses are generally consistent with each other.

This general consistency in analytical results gives further credibility to the conclusions reached, and also further tends to validate the QJM as an analytical tool and as a reliable simulation of modern combat.

HYPOTHETICAL WARSAW PACT OFFENSIVE IN THE FULDA GAP AREA

HERO has demonstrated in prior studies that the QJM methodology for retrospective analysis can be extrapolated for use as a reliable predictive simulation of future combat by introducing into the formulae the known effects of technology in calculations of weapons effects, mobility effects, and vulnerability effects.* Accordingly, one of the scenarios used in the

*HERO report, Feasibility of Net Assessment of NATO-Warsaw Pact Forces by Means of the Quantified Judgment Model (U), September 1973; HERO Report, Analysis of Implications of Surprise in Scenarios of Conventional and Tactical Nuclear Combat in Europe, July 1978; T.N. Dupuy, Numbers, Predictions & War (New York, 1979).

Table 5-9. Comparison of a limited historical analysis with QJM analysis

	Historical Data Only			QJM Analysis Factor	Historical Factor
	Fortified	Hasty	Factor		
Attacker					
KM per day advance	1.58	6.19	0.26	0.13	1.94
% Casualties/KM	1.50	0.26	5.77	8.00	0.72
% Tank losses/KM	30.13	2.20	13.70	6.18	2.22
Defender					
% Casualties/KM	2.25	0.44	5.11	5.95	0.86
% Tank losses/KM	22.75	2.11	10.78	3.61	2.99

study, Analysis of Implications of Surprise in Scenarios of Conventional and Tactical Nuclear Combat in Europe, was adapted for use in a hypothetical Warsaw Pact (WP) offensive against NATO, focussing on the US V Corps sector in the Fulda Gap area, in the early 1980s, as follows:

- Conventional surprise WP attack, NATO in hasty/mobile posture;
- Conventional surprise WP attack, NATO in fortified posture;
- Surprise WP attack with tactical nuclear weapons, NATO in hasty/mobile posture, responding in kind;
- Surprise WP attack with tactical nuclear weapons, NATO in fortified posture, responding in kind.

Fulda Gap, 1980's, Comparison of NATO Hasty and Fortified Postures

It was decided to give the WP the benefit of the advantages conferred by a surprise attack, since the Implications of Surprise study indicated that the Soviets would not be likely to attack unless they were convinced that they could achieve surprise. Also, for the purposes of this study, it was felt that a surprise attack would provide the best test of the utility of fortifications. Similarily it was assumed that this would be a "main effort" attack, with the bonus in combat power and advance rates historically accruing from such attack posture.

Following the same reasoning, it was believed that the best test of the utility of field fortifications in a tactical nuclear environment would be the extent to which they coulddeal with a situation in which the WP had the benefit of first use of tactical nuclear weapons.

Fulda Gap, 1980's, Comparison of NATO Hasty and Fortified Postures, Conventional Weapons Only

Table 5-10 shows the effects that field fortifications would have upon the defensive capability of NATO (US V Corps) in the event of a surprise attack in the Fulda Gap area. This effect is shown by a comparison of QJM analyses of the V Corps in a fortified posture and in a hasty posture. The principal results of fortifications are:

- WP advance rate/day is reduced to 31% of that in hasty defense (or by a factor of 3.2)
- WP is delayed 7.7 days (9.5 days as compared to 1.8 days)
- WP casualty rate/day is increased by a factor of 1.8
- WP casualty rate/km is increased by a factor of 8.0
- WP tank loss rate/km is increased by a factor of 5.6
- NATO casualty rate/day is increased by a factor of 1.6 (88% of WP increase)

Table 5-10. Fulda Gap. Comparison of hasty and fortified posture, conventional combat

			Attacker				Defender			
	Dist. Adv. KM	Days to Break-through	%Cas /Day	% Tank Loss /Day	%Cas /KM	% Tank Loss /KM	%Cas /Day	% Tank Loss /Day	%Cas /KM	% Tank Loss /KM
Hasty	25.53	1.81	0.36	3.56	0.01	0.14	1.73	10.56	0.07	0.41
Fortified	8.02	9.49	0.64	6.34	0.08	0.79	2.71	15.21	0.34	1.90
F/H	0.31	0.19	1.78	1.78	8.00	5.64	1.57	1.44	4.86	4.63
(H/F)	(3.18)	(5.24)								

Days Saved: 7.68

o NATO tank loss rate/day is increased by a factor of 1.4 (31% of WP increase)

o NATO casualty rate/km is increased by a factor of 4.9 (61% of WP increase)

o NATO tank loss rate/km is increased by a factor of 4.6 (82% of WP increase).

It should be noted that these rates include a 24-hour covering force battle, in which the NATO posture in both instances is Delay.

Fulda Gap, 1980's, Comparison of NATO Hasty and Fortified Postures, Conventional and Tactical Nuclear Weapons

A discussion of the considerations relating to the employment of nuclear weapons in this study is contained in Chapter 4, and Appendix B.

Table 5-11 shows the effects that field fortifications would have on the defensive capability of the NATO formation (US V Corps) in the event of a surprise WP attack in the Fulda Gap area, followed by the use of tactical nuclear weapons by WP forces in an effort to assure a breakthrough, in turn followed by a NATO response in kind. It is clear that, in the event of a hasty defense, there would be no need for use of tactical nuclear weapons by the WP; the excursion is made here, however, for comparative purposes.

It should be noted that the comparisons in the nuclear exchange examples reflect 36 hours of conventional combat before the WP use of tactical nuclear weapons.

If the force ratios were to remain the same after H+60, the Warsaw Pact would break through to the rear of the NATO main battle area (MBA) in about 3.18 days. However, the Warsaw Pact losses due to radiation effects during the period subsequent to the exchange would clearly be very much greater than those of the well-protected NATO defenders. Although the excursion was not carried beyond H+60 hours, it is evident that the breakthrough would not take place before the beginning of D+4.

The principal results of fortifications vs. hasty defense in a nuclear exchange situation are:

o WP advance rate is reduced to 43% of that against hasty defense

o WP is delayed about 2.2 days (4.0 days as compared to 1.8)

o WP casualty rate/day is virtually unchanged

Table 5-11. Fulda Gap. Comparison of hasty and fortified posture, nuclear exchange

	Dist. Adv. Km/Day	Days to Break-through	Attacker %Cas /Day	Attacker % Tank Loss /Day	Attacker %Cas /Km	Attacker % Tank Loss /Km	Defender %Cas /Day	Defender % Tank Loss /Day	Defender %Cas /Km	Defender % Tank Loss /Km
Hasty	25.53	1.78	9.50	14.76	0.37	0.58	6.31	29.27	0.25	1.15
Fortified	11.16	4.00	9.74	15.58	0.87	1.40	6.26	32.92	0.56	2.95
F/H	0.43	0.56	1.03	1.06	2.35	2.41	0.99	1.12	2.24	2.57
H/F)	(2.29)	(1.79)								
Days Saved: 2.22										

- WP tank loss rate/day is virtually unchanged
- WP casualty rate/km is increased by a factor of 2.4
- WP tank loss rate/km is increased by a factor of 2.4
- NATO casualty rate per day is virtually unchanged
- NATO tank loss rate/day is increased by a factor of 1.1
- NATO casualty rate /km is increased by a factor of 2.2
- NATO tank loss rate/km is increased by a factor of 2.6

Since, however, it is most unlikely that the WP would need to use tactical nuclear weapons against a NATO hasty-mobile defense, the efficiency of the use of such weapons is best determined by comparing the results of a tactical nuclear attack with a conventional attack against a fortified NATO posture. This, of course, will also evaluate the value of fortifications.

Table 5-12 is a comparison of the relative effects using tactical nuclear weapons and conventional weapons against a fortified defense posture.

- WP advance rate is increased by a factor of 1.4 in a tactical nuclear exchange
- WP regains about 5.5 days, but still requires about 4 days to achieve a breakthrough
- WP casualty rate/day is increased by a factor of 15.2
- WP tank loss rate/day is increased by a factor of 2.5
- WP casualty rate/km is increased by a factor of 10.9
- WP tank loss rate/km is increased by a factor of 1.8
- NATO casualty rate/day is increased by a factor of 2.3
- NATO tank loss rate/day is increased by a factor of 2.2
- NATO casualty rate/km is increased by a factor of 1.7
- NATO tank loss rate/km is increased by a factor of 1.6.

Thus it is obvious that by use of tactical nuclear weapons WP is able to gain some acceleration in advance rate, and achieve a breakthrough more quickly, but at a tremendous cost in lives and materiel. The severe losses that NATO forces would also suffer would be much smaller than those of the WP, and the availability of fortifications in a tactical nuclear exchange situation would make the NATO defense situation much more viable than in a hasty/mobile defense situation.

Table 5-12. WP surprise attack on NATO fortified defense. Comparison of conventional and nuclear exchange outcomes

	Dist. Adv. KM/Day	Days to Break-through	Attacker %Cas /Day	Attacker % Tank Loss /Day	Attacker %Cas /KM	Attacker % Tank Loss /KM	Defender %Cas /Day	Defender % Tank Loss /Day	Defender %Cas /KM	Defender % Tank Loss /KM
Conv.	8.02	9,49	0.64	6.34	0.08	0.79	2.71	15.21	0.34	1.90
Nuclear Exchange	11.16	4.00	9.74	15.58	0.87	1.40	6.26	39.92	0.56	2.95
TN/Conv.	1.39	2.98	15.22	2.46	10.88	1.77	2.31	2.16	1.65	1.55

Days regained by attacker: 5.49

CHAPTER VI

IMPLICATIONS AND CONCLUSIONS

GENERAL IMPLICATIONS

It is evident from the foregoing analyses that in modern combat (World War II and since) field fortifications have apparently invariably enhanced the combat capabilities of defenders to a substantial degree, and have substantially slowed the rates of advance of attackers. This is an apparent truism that should be seriously considered in planning for defense of NATO in Central Europe. The political implications of such planning are beyond the scope of this study, but from these results (and those in two other HERO studies)* some valid observations can be made about military implications and measures that might be advantageous toward strengthening the NATO defense posture.

Most of these examples of the effects of field fortifications demonstrate one of their important benefits. They permit a defending force to commit only a small proportion of its strength in the front line, freeing substantial forces, particularly mobile elements, for use in mobile reserves for counterattack or [illegible] offensive. And the fortifications provide time to use these reserves effectively. The two Kursk examples, and the Bar Lev Line-Suez Canal example, are particularly useful illustrations of this benefit. Considering how inadequacy of forces is leading the US Army to adopt a dangerous tactical doctrine which neglects mobile reserves, this is a very important consideration.

Although the scope of the current study did not include attempting to determine which elements of a typical field fortification barrier system made the greatest contribution toward enhancing defensive capabilities and degrading attackers' rates of advance, in one of the earlier studies -- Historical Evaluation of Barrier Effectiveness -- HERO made a start toward the elaboration of a methodology which would permit such determination. This methodology is based essentially on the concepts underlying the QJM. Its principal elements are:

1. Quantitative values for different levels of defensive posture, ranging from 1.15 to 1.6.

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* HERO, Historical Evaluation of Barrier Effectiveness (Dunn Loring, Virginia, 1974), and Implications of Surprise.

2. Proportional quantitative relationships among the effects of field fortifications, demolitions, mines, and constructed obstacles.

3. Planning factors for the construction effort required to achieve a specific quantitative value for elements of a defensive barrier.

4. Effects of circumstantial environmental variables upon construction efforts.

5. Effects of varying kinds of terrain upon the combat value of a defensive posture.

6. Relationship of obstacle delay capabilities to force ratios.

7. Delay effects of varying kinds of terrain features and obstacles.

DETERRENCE IMPLICATIONS FOR NATO

In HERO's recent study on Implications of Surprise it was concluded that a Warsaw Pact offensive against NATO was unlikely unless the Soviets could be confident of success, probably as a result of an opportunity to achieve surprise. It was also concluded that the availability of field fortifications might so bolster NATO's relative combat strength as to make a Warsaw Pact attack upon NATO in central Europe even more unlikely.

The results of this study tend to corroborate that tentative conclusion. Current Soviet military literature indicates that Warsaw Pact planners expect daily advances in the order of 40-50 kilometers per day under non-nuclear conditions, and advances of 50-80 kilometers per day under nuclear conditions. The results of this study suggest that these rates are probably unrealistic, but that rates in the order of 25-35 kilometers per day might reasonably be expected against a NATO hasty-mobile defense, at least if Warsaw Pact forces achieve a measure of surprise.

But this study also shows that against field fortifications Warsaw Pact advance rates would be likely to be in the order of 5-10 kilometers per day in a non-nuclear situation, and perhaps 10-15 kilometers per day in a nuclear situation. These are rates less than one-fifth of what the Soviets expect and half to one third of what the study indicates is realistic. Soviet doctrine makes it very clear that the Soviets fully understand the delay and strengthening effects of field fortifications; their simulations or assessments of the effect which field fortifications would have upon their advance rates would unquestionably be comparable, even if not identical, to the results presented on earlier pages of this study.

The great significance of delay, of course, is not just the prolongation of the battle and increase in casualties -- although these are not insignificant considerations in themselves. The consideration which will be uppermost in the minds of Soviet planners will be the opportunity which delays will provide for timely arrival of NATO reinforcements, from France, from the United Kingdom, and particularly from the United States.

Thus the presence of substantial NATO field fortifications would severely reduce the benefits which the Soviets could gain from a surprise attack, and even under the best of conditions must significantly reduce the confidence which the Soviet planners and leaders can have in the successful outcome of either a conventional or tactical nuclear conflict in central Europe.

The contribution field fortifications could make to NATO's deterrent posture, therefore, is substantial.

It might be further argued, however, that if NATO were to start building a fortified barrier along the front of Allied Command Europe, Warsaw Pact planners would perceive it as an intolerable threat to the possibility of Warsaw Pact success in war. Thus -- it could be argued -- they would be tempted to carry out a preemptive attack before construction could reach the point of combat effectiveness.

Such attack would be credible only if it is assumed that the USSR is actively contemplating military operations in Central Europe within some definite time period. Although experts on Soviet military affairs and doctrine discount the reasonableness of such an assumption, it would be foolhardy to ignore it as a possibility. During the period of construction, therefore, NATO forces should be particularly alert, and should probably have a higher proportion of strength deployed to the likely battle zone than is now the case. The increased alertness of NATO would reduce the chance of Warsaw Pact surprise, until the fortifications were ready, and in this interim period would provide the deterrent effect noted in HERO's Implications of Surprise study.

OPERATIONAL IMPLICATIONS FOR NATO

As pointed out in HERO's Barrier Effectiveness study, a field fortification barrier has two principal effects on the progress of combat:

a. It enhances the combat capability of the defender, and

b. It degrades the advance rate of the attacker.

Both of these effects are corroborated by this current study.

In the Implications of Surprise HERO concluded that the effectiveness of the current NATO deterrent would be increased by an obvious enhancement with field fortifications of NATO defensive capability against a Warsaw Pact attack -- with or without surprise -- and with or without concurrent tactical nuclear operations.

The HERO study indicated that without the availability of field fortifications a Warsaw Pact attack, with or without surprise, was likely to defeat NATO in Central Europe. Therefore, it seemed evident that there is strong reason for taking actions that would (in the event of a Warsaw Pact attack) improve defensive capability, and degrade the Warsaw Pact advance rate, and that further might obviate the likelihood of such attack by a clearly and credibly improved deterrent posture. The current study validates these conclusions by showing that historical experience indicates that field fortifications have made significant contributions to slowing or even temporarily halting an attack. The question then becomes, what sort of plan for fortifications would be practicable in the current NATO situation?

A major point of departure in the initiation of plans and actions to enhance NATO defensive capability by the incorporation of field fortifications into the NATO defensive system and plan must be an awareness of the limitations as well as the capabilities of field fortifications. There is nothing in the data or analysis of previous sections of this report to modify one of the fundamental principles of war: positive results in warfare can be achieved only by offensive action. Thus, no matter how much field fortifications can enhance defensive capability (and the analysis presented in this report demonstrates that the enhancement is considerable), this should in no way be construed as suggesting that either the counter-attack or general offensive capability of NATO forces should be degraded. On the contrary, the case studies in this report suggest that field fortifications can contribute to an overall economy of forces which should

result in an actual increase in overall offensive capability without any increase in the current NATO force levels.

With this balanced perspective of the relationship and interrelationship of offensive and defensive capabilities in mind, the principal military considerations in approaching the problem of enhancing NATO defensive capability by the judicious use of a field fortification barrier are:

1. General planning to accomodate current NATO forces and force structure to an enhanced, defensive posture capability.

2. Integration of the fortifications into the overall ACE strategic or operational plan.

3. Integration of the fortifications into the tactical plans of the several NATO corps and divisions.

4. Availability of resources for construction: funds, materials, manpower.

5. Adaptation as necessary of overall and local force structures to a defensive plan based upon the availability of field fortifications.

6. Within the strategic and tactical plans, relating the fortifications to the most suitable terrain, with particular consideration given to the adaptation of urban areas to defensive purposes.

RESEARCH REQUIREMENTS

The planning suggested above would be greatly facilitated by a reliable, tested, and validated methodology that can assess the relative value and interrelationships of the various components of a barrier-fortification system. In other words there is an urgent need for continuing the research effort begun by HERO in 1974 in its study Historical Evaluation of Barrier Effectiveness. Some work done at the US Army Construction Engineering Research Laboratory, Champaign, Illinois, is unquestionably relevant.

Such planning could also be facilitated by a review of all relevant research, planning, and analysis already performed in the United States, in the research establishments of the NATO allies, and in such NATO organizations as SHAPE and SHAPE Technical Centre. HERO is aware of relevant work being done directly or indirectly for the Defense Nuclear Agency, in various staffs and installations under the surveillance of the Chief of Engineers, at Sandia Laboratories, in British analytical establishments, and in France. Undoubtedly much more relevant work has been done at the

US Army Combined Arms Center and at various Army service schools as well as various establishments of other NATO allies.

CONCLUSIONS

It is concluded that:

1. In modern historical combat, field fortifications have enhanced the combat capability of defending forces, and degraded the combat capability of attacking forces.

2. While the extent of enhancement of defense and degradation of attack clearly depend upon the nature and scope of the fortifications, comparisons of a defense based on extensive fortifications with a hasty/mobile defense with little or no fortification suggest the following:

a. The attacker's advance rate against fortifications has been reduced to about 20% of that against a hasty/mobile defense;

b. The attacker's daily casualty rate has been increased by a factor of about 1.3;

c. The attacker's daily tank loss rate has been increased by a factor of about 1.3;

d. The attacker's casualty rate per kilometer advanced has been increased by a factor of about 8.0.

e. The attacker's tank loss rate per kilometer advanced has been increased by a factor of about 6.2;

f. The defender's daily casualty rate has been reduced by a factor of about 0.8;

g. The defender's daily tank loss rate has been reduced by a factor of about 0.7;

h. The defender's casualty rate per kilometer lost has been increased by a factor of about 6.0; this is about 74% of the similar rate for the attacker;

i. The defender's tank/loss rate per kilometer lost has been increased by a factor of about 3.4; this is about 58% of the similar rate for the attacker.

3. A simulation of a surprise Warsaw Pact conventional attack against NATO forces in the Fulda Gap area in the early 1980s indicates that enhancement of defender capability and degradation of attacker capability by the presence of fortifications on a contemporary battlefield would be approximately as follows:

a. The WP advance rate would be reduced to about 31% of that against hasty defense;

b. The WP would be delayed about 7.7 days (about 9.5 as compared to 1.8);

c. The WP casualty rate/day would be increased by a factor of 1.8;

d. The WP tank loss rate/day would be increased by a factor of 1.8;

e. The WP casualty rate/km would be increased by a factor of 8.0;

f. The WP tank loss rate/km would be increased by a factor of 5.6;

g. The NATO casualty rate/day would be increased by a factor of 1.6, or 88% of the WP rate;

h. The NATO tank loss rate/day would be increased by a factor of 1.4, or 81% of the WP rate;

i. The NATO casualty rate/km would be increased by a factor of 4.9; or 61% of the WP rate;

j. The NATO tank loss rate/km would be increased by a factor of 4.6; or 82% of the WP rate.

4. If the Warsaw Pact is able to achieve surprise in a conventional attack against a hasty/mobile NATO defense, the likelihood of WP success is such that resort to tactical nuclear weapons by the WP is unlikely.

5. A simulation of a surprise Warsaw Pact attack including a nuclear exchange (after Soviet first use of tactical nuclear weapons) shows the following major differences from the results of a conventional surprise attack against a fortified defense:

a. The WP advance rate/day would be increased by a factor of 1.4.

b. The WP regains about 5.5 days, but would still require about 4 days to achieve a breakthrough;

c. The WP casualty rate/day would be increased by a factor of about 15.2;

d. The WP tank loss rate/day would be increased by a factor of about 2.5;

e. The WP casualty rate/km would be increased by a factor of about 10.9;

f. The WP tank loss rate/km would be increased by a factor of about 1.8;

g. The NATO casualty rate/day would be increased by a factor of about 2.3; or 15% of the WP rate;

h. The NATO tank loss rate/day would be increased by a factor of about 2.2; or 88% of the WP rate;

i. The NATO casualty rate/km would be increased by a factor of about 1.7; or 15% of the WP rate;

j. The NATO tank loss rate/km would be increased by a factor of about 1.6; or 88% of the WP rate.

6. It is likely that the installation of field fortifications would be viewed by Soviet planners as affecting the outcome of a WP attack in central Europe in several ways, including:

a. Potential WP advance rates against NATO forces would be reduced (according to HERO calculations) from about 25-35 kilometers pe day to about 5-15).

b. The delay would provide NATO with additional time (HERO estimates two to eight days), permitting the arrival of reinforcements from France, from the United Kingdom, and from the United States.

c. Casualty costs to WP forces would increase significantly, while NATO losses would be reduced, or only slightly increased.

d. Confidence in an outcome favorable to the Warsaw Pact would be diminished.

7. NATO's deterrent posture would be enhanced by likely Soviet perceptions of the effects of field fortifications.

8. The remote possibility of a Warsaw Pact preemptive attack to forestall the effectiveness of fortifications can be offset by NATO alertness and increased forward deployments during the construction period.

9. These results suggest the military desirability that a fortified barrier be constructed promptly to cover the front of the Central Army Group of Allied Command Europe.

10. These results are consistent with time-proven principles:

a. Positive combat results are possible only from offensive action;

b. Defensive posture is required by forces lacking strength for offensive, or conserving strength for offensive at another time or place.

11. The principal military considerations affecting construction of such a fortified barrier are:

a. General planning to accomodate current NATO forces and force structure to an enhanced defensive posture capability;

b. Integration of the fortifications into the overall Allied Command Europe strategic or operational plan;

c. Integration of the fortifications into the tactical plans of the several NATO corps and divisions;

d. Availability of resources for construction: funds, materials, manpower;

e. Adaptation as necessary of overall and local force structures to a defensive plan based upon the availability of field fortifications;

f. Within the strategic and tactical plans, relating the fortifications to the most suitable terrain, with particular consideration given to the adaptation of urban areas to defensive purposes.

12. The foregoing conclusions are based on a small number of examples of combat experience. The conclusions should be further validated by repeating the process with a larger data base.

13. Considerable research and analysis relevant to the possible development of NATO field fortifications has been performed in the United States and other NATO countries in recent years, and should be reviewed for possible contributions to future planning for such fortifications.

RECOMMENDATIONS

1. That a fortified barrier be constructed promptly to cover the front of the Central Army Group. Initial steps should include reinforcing/taking advantage of national barriers, e.g., constructing canal or river banks to preclude armor vehicle fording or swimming across the canal/river.

2. That HERO be authorized to work in coordination with the Engineering Construction Laboratory to extend, refine, and validate the methodology begun in the study, Historical Evaluation of Barrier Effectiveness.

3. That a NATO-wide review of all planning and analysis relevant to the development of a field fortification system along the front of Allied Command Europe be initiated as soon as possible. Since land is scarce, politically acceptable solutions must be found (such as the type recommended in number one, above).

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APPENDIX A

POSTURE DEFINITIONS FOR THIS STUDY

Attack: To strike the enemy for one of the following purposes:

a. Develop the situation;

b. Defeat enemy forces;

c. Secure territory or terrain;

d. Deprive the enemy of required resources;

e. Divert the enemy's attention from other areas.

Hasty defense: A defense normally organized while in contact with the enemy or when contact is imminent, and time available for the organization is limited. It is characterized by improvement of the natural defensive strength of the terrain by utilization of foxholes, emplacements, and obstacles; if occupied for a protracted period the hasty defense position can be improved to the status of prepared or fortified defense.

Prepared defense: A defense system prepared by a defender who has had sufficient time to organize the defensive position, but (due to lack of time or resources) with less than the strength of a fortified position.

Fortified defense: A comprehensive, coordinated defense system prepared by a defender with sufficient time to complete planned entrenchments, field fortifications, and obstacles in such a manner as to permit the most effective possible employment of defensive firepower.

Delay (delaying action): A retrograde movement in which the defender inflicts maximum delay and damage on an advancing enemy to gain time, without becoming decisively engaged in combat or being outflanked.

Withdrawal from action: A retrograde maneuver whereby a force disengages from combat, or contact with an enemy force, in accordance with the will of the commander.

APPENDIX B

HERO'S TACTICAL NUCLEAR SUB-MODEL

In order to compare and contrast the effects of the introduction of tactical nuclear weapons to a conventional battlefield in HERO's classified study Analysis of Implications of Surprise in Scenarios of Conventional and Tactical Nuclear Combat in Europe (U),* it became necessary to develop a sub-model to be used with HERO's Quantified Judgment Model. In much the same way that the Quantified Judgment Model was developed by analysis of data from historical engagements, the Tactical Nuclear Sub-Model (TNSM) was developed by using as "hypothetical history" results of analyses of tactical nuclear operations performed by scenario-dependent models of tactical nuclear combat. In spite of some crudeness in the sub-model, it is believed as suitable for use in this study as in the earlier study. This appendix briefly describes the development of the sub-model, and its use in this study. The methodology is discussed in considerably greater detail in the referenced study report.

First, tables were prepared, in terms and values consistent with the QJM approach for conventional weapons, to show the firepower shock effects of nuclear weapons in Operational Lethality Index (OLI) units, and the standard casualty effects of tactical nuclear weapons against exposed troops in the open. The principal reference sources for this were two 1976 reports prepared by US Army DCSOPS: "Battlefield Theater Nuclear Force (TNF) Mix Analysis," (BTNFMA) and "The TNF Wargamers' Guide."

Then procedures were developed to modify these "proving ground" values by a variety of environmental and operational variable factors to represent actual circumstances of combat. It then became possible to analyze the results of the "hypothetical history" examples to determine the relationship between these theoretical casualty values and the "real world" battlefield results which tactical nuclear specialists had derived from their scenario-dependent models of tactical nuclear combat. This was done by using six examples of hypothetical history scenarios from such models.

The theoretical, or tabular, casualties were calculated for each of the six hypothetical history examples, as they would have occurred with

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* Prepared for Office Deputy Chief of Staff for Operations and Plans, Department of the Army, July 1978.

an average density of one man per 4,000 square meters. Those were compared with the actual casualties as they occurred in the scenarios, and a formula was then developed to convert the tabular casualties to the actual casualties. That formula is:

$$\text{Personnel losses} = \text{tabular casualties} \cdot \sqrt{\frac{N \cdot (N \text{ per wpn} + 200)}{\text{Tanks} + \text{APCs}}} \cdot \text{Men per meter} \cdot \frac{U_V}{469}$$

Where:

N is the personnel strength of the target force.

U_V is a vulnerability factor representing the extent to which troops are dug in or the position is fortified.

Losses of major materiel items were then derived by applying relevant factors to the personnel results (as shown in rules, below).

Tentative rules for TNSM were developed to indicate ways in which TNSM differs from the QJM. They are subject to modification when more examples are available for analysis.

1. The OLI values of tactical weapons, as in HERO's tables, are in full shock effect for four hours and ineffective after 24 hours.

2. OLI values for all tactical nuclear weapons are added to the normally-calculated Combat Power value.

3. Optimum air-delivered accuracy of tactical nuclear weapons is assumed if the total available close air support OLI is at least double the air defense OLI. It is assumed that this accuracy drops off to a minimum of 50% accuracy if air OLI is equal to, or less than, air defense OLI.

4. It is assumed that there is no degradation in ground-delivered weapons up to 75% of maximum range, with a straight line dropoff to 50% accuracy at maximum range.

5. It is assumed that, no matter how well prepared troops are, there will be a disruptive effect when tactical nuclear weapons are first used in a campaign. Lacking any experience data, it is assumed that the effectiveness degradation due to disruption will be identical with the QJM values for Substantial Surprise, lasting for one day only.

6. All tactical nuclear weapons-inflicted casualties are in addition to other attrition calculations.

7. Casualties are all assessed against the unit in whose sector the weapon is detonated.

8. Tactical weapons strikes more than 10 kilometers beyond the FEBA, within range of available artillery or air delivered weapons, yield casualties half those for tactical nuclear weapons detonated within 10 kilometers of the FEBA.

9. Immediate casualties are calculated by the formula given above.

10. After 24 hours additional casualties resulting from the tactical nuclear strike will be 50% of immediate casualties. For each of the next three days there will be an additional 25% of immediate casualties.

11. Tank losses are calculated at 1.3 x the immediate casualty rate.

12. APCs, artillery, antiaircraft weapons, and other materiel losses are calculated at the immediate casualty rate.

For the two nuclear exchange scenarios in this study, packages of 90 tactical nuclear weapons each for NATO and Warsaw Pact forces were assumed. These weapons were distributed among artillery, missile, and air-delivered weapons. It was assumed the WP would make its first use of its 90 tactical nuclear weapons after twelve hours of attack against the NATO main battle position. It was further assumed that NATO would respond beginning twelve hours later. Losses and effects were calculated on the bases of the formula and the rules listed above.

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Los Alamos National Laboratory
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Sandia National Lab
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Decisions and Designs, Inc
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E-Systems, Inc
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Pacific-Sierra Research Corp
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R&D Associates
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TRW Electronics & Defense Sector
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